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Technology Evaluation Report
SITE (Superfund Innovative Technology Evaluation) Program Demonstration Test Shirco Pilot-Scale Infrared Incineration System at the Rose Township Demode Road Superfund Site. Volume 1

Enviresponse, Inc., Livingston, NJ

Prepared for:

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Technology Evaluation Report:

SITE Program Demonstration Test Shirco Pilot-Scale Infrared Incineration System at the Rose Township Demode Road Superfund Site

Volume I

SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

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16. ABSTRACT

A Superfund Innovative Technology Evaluation (SITE) Program demonstrated the Shirco Infrared System (pilot plant) for thermally processing PCB waste at Rose Township, Michigan. The process was evaluated by the U.S. EPA and is reported in Volume I of the report. Volume II of the report contains the operating log sheets, sampling reports and analytical reports.

Results reported in Volume I indicated that PCB was removed from the feed material with a DRE greater than 99.99%. The destructive ratio (percent of PCB in the ash compared to feed) was greater than 83 percent resulting in a less than 1 ppm concentration in the ash. Particulate emissions, products of incomplete combustion (PICs) and acid gas emissions were below any standards. Metals in the ash leached by the TCLP and EP Tox. were below suggested standards.

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SITE Program Demonstration Test Shirco Pilot-Scale Infrared Incineration System at the Rose Township Demode Road Superfund Site

Volume I

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NOTICE

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FOREWORD

The Superfund Innovative Technology Evaluation (SITE) program was authorized in the 1986 Superfund amendments. The program is a joint effort between EPA's Office of Research and Development and the Office of Solid Waste and Emergency Response. The purpose of the program is to assist the development of hazardous waste treatment technologies necessary to implement new cleanup standards which require greater reliance on permanent remedies. This is accomplished through technology demonstrations which are designed to provide engineering and cost data on selected technologies.

This project consists of an analysis of Shirco's Pilot-Scale Infrared Incineration System and represents the third field demonstration in the SITE program. The technology demonstration took place at an abandoned waste site which comprises the Demode Road Superfund Site in Rose Township, Michigan. The demonstration effort was directed at obtaining information on the performance and cost of the system for use in assessments at other sites. Documentation will consist of two reports. This Technology Evaluation Report describes the field activities and laboratory results. An Applications Analysis Report will follow and provide an interpretation of the data and conclusions on the results and potential applicability of the technology.

Additional copies of this report may be obtained at no charge from EPA's Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, Ohio, 45268, using the EPA document number found on the report's front cover. Once this supply is exhausted, copies can be purchased from the National Technical Information Service, Ravensworth Bldg., Springfield, VA, 22161, (702) 487-4600. Reference copies will be available at EPA libraries in their Hazardous Waste Collection. You can also call the SITE Clearinghouse hotline at 1-800-424-9346 or (202) 382-3000 in Washington, DC to inquire about the availability of other reports.

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ABSTRACT

The Shirco Pilot-Scale Infrared Incineration System was evaluated during a series of seventeen test runs under varied operating conditions at the Demode Road Superfund Site located in Rose Township, Michigan. The tests sought to demonstrate the effectiveness of the unit and the technology in thermal destruction of soil contaminants, as recommended by the Remedial Investigation and Feasibility Study conducted between 1984 and 1986. The report includes a process description of the unit and field operations documentation including a discussion of the operational history during the test program, a summary of operating conditions, and the operating log data. The report also includes sampling and analytical procedures and data along with the approved quality assurance project plan. The report provides a performance evaluation of the unit based on the test program data and observations and an overall unit cost analysis and evaluation. Based on the above information, the report provides the initial data and evaluation criteria to enable the EPA to determine the applicability of the Shirco technology to Superfund site investigations and cleanups throughout the country. The report covers a period from May 11, 1987 to September 30, 1988, with the test demonstration of the unit occurring from November 2, 1987 to November 13, 1987.

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ABBREVIATIONS AND SYMBOLS

AAS	Atomic absorption spectroscopy
acfm	Actual cubic feet per minute
APC	Air pollution control
Btu	British thermal units
cc	Cubic centimeter
CEM	Continuous emission monitor
CFR	Code of Federal Regulations
Cl	Chlorine
CO	Carbon monoxide
CO_2	Carbon dioxide
DE	Decontamination efficiency
DGM	Dry gas meter
DRE	Destruction and removal efficiency
dscf	Dry standard cubic feet
dscfm	Dry standard cubic feet per minute
dscm	Dry standard cubic meters
dscmm	Dry standard cubic meters per minute
ECD	Electron capture detection
EMB	Emissions Measurement Branch
EPA	U.S. Environmental Protection Agency
EP Tox	EP Toxicity Test Procedure
FID	Flame ionization detection
ft	Feet
FWEI	Foster Wheeler Enviresponse, Inc.
g	Grams

ABBREVIATIONS AND SYMBOLS (continued)

gal	Gallons
GC	Gas chromatograph
GMW	General Motor Works
gpm	Gallons per minute
HCl	Hydrogen chloride
HHV	High heating value
ICAP	Inductively coupled argon plasma
ID	Inside diameter
in	Inches
J	Joules
kg	Kilograms
Kw	Kilowatts
L	Liters
lb	Pound
m	Meters
MDNR	Michigan Department of Natural Resources
mg	Milligrams
min	Minutes
ml	Milliliters
m	micron
ug	Micrograms
MM5	Modified Method 5
MS	Mass spectrophotometer
NBS	National Bureau of Standards
ND	Not detected
NDIR	Non dispersive infrared

ABBREVIATIONS AND SYMBOLS (continued)

ng	Nanograms
Nm^3	Normal cubic meters
NO_x	Nitrogen oxide
OAQPS	Office of Air Quality, Planning, and Standards
OD	Outside diameter
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
O_2	Oxygen
Pb	Lead
PCBs	Polychlorinated biphenyls
PCC	Primary combustion chamber
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzofuran
PIC	Product of incomplete combustion
POHC	Principal organic hazardous constituent
PP	Priority pollutant
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per trillion
psig	Pounds per square inch gauge
PUF	Polyurethane foam
%	Percent
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RF	Response Factor
RI/FS	Remedial Investigation/Feasibility Study

ABBREVIATIONS AND SYMBOLS (continued)

ROD	Record of Decision
RREL	Risk Reduction Engineering Laboratory
S	Sulfur
S&A	Sampling and Analysis
SARA	Superfund Amendments and Reauthorization Act of 1986
SASS	Source assessment sampling system
SCC	Secondary combustion chamber
SCFM	Standard cubic feet per minute
sec	Seconds
SITE	Superfund Innovative Technology Evaluation Program
sq ft	Square feet
SV	Semivolatile
TCDD	Tetrachlorodibenzo-p-dioxin
TCDF	Tetrachlorodibenzofuran
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total dissolved solids
THC	Total hydrocarbons
TOC	Total organic carbon
TSCA	Toxic Substances Control Act of 1976
TSS	Total suspended solids
UV	Ultraviolet
v	Volume
V	Volatile
VOA	Volatile organic analysis
VOST	Volatile organic sampling train
WC	Water column
wt	Weight

CONVERSIONS

To convert from	to	Multiply by
Btu/lb	J/g	2.326 E+00
Cu ft	m^3	2.832 E-02
Cu yd	m^3	7.646 E-01
ft	m	3.048 E-01
^oF	^oC	t_C $(t_F-32)/1.8$
gal	m^3	3.785 E-03
HP	kW	7.46 E-01
lb	kg	4.535 E-01
Btu/hr	J/hr	1.055 E+03

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This report was prepared for EPA's Superfund Innovative Technology Evaluation (SITE) Program by Mr. Seymour Rosenthal, Task Manager for Foster Wheeler Enviresponse, Inc. for the U.S. Environmental Protection Agency under Contract No. 68-03-3255.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), the U.S. Environmental Protection Agency's (EPA) Offices of Research and Development (ORD) and Solid Waste and Emergency Response (OSWER) have established a formal program to accelerate the development, demonstration, and use of new or innovative technologies for hazardous waste site cleanups. This program is called the Superfund Innovative Technology Evaluation (SITE) Program.

The major objective of this demonstration program is to develop reliable cost and performance information on innovative alternative technologies, so that they can be considered in Superfund decision making. Common measurement, monitoring, and evaluation guidelines and protocols have been developed by ORD and are used to collect data and information from the demonstrations. SITE demonstrations usually will be conducted at Superfund Federal or State sites. Federal facilities, private sites, and EPA or developer test and evaluation facilities can be used.

One site that has been chosen to demonstrate an innovative technology is the Demode Road Superfund Site located in Rose Township, Oakland County, Michigan, approximately 40 miles northwest of Detroit.

The 12-acre waste site first was used for disposal and storage of industrial wastes in 1966. Bulk wastes brought to the site were discharged to surface and shallow lagoons and pits. Drums of waste either were buried, dumped into disposal pits, or stockpiled. The site was used as a disposal facility through 1968, and possibly was used on an intermittent basis until 1971.

In June 1979, the Michigan Department of Natural Resources (MDNR) inspected the site and discovered many drums leaking. Sampling of the drums showed the contents to be paint sludges, solvents, polychlorinated biphenyls (PCBs), oils and greases, phenols, and heavy metals. MDNR proceeded to remove over 5,000 drums of waste material. In 1983, an additional 1,500 tons of contaminated soil were removed.

MDNR conducted a Remedial Investigation and Feasibility Study

(RI/FS) of the site from 1984 through 1986. The data from the RI/FS indicated that the soils at the site contained concentrations of PCBs as high as 980 ppm, lead concentrations as high as 1,480 ppm, and quantities of other organics and heavy metals. The RI/FS recommended that the site be cleaned up by extraction and treatment of the contaminated groundwater and thermal destruction of contaminants in the soil. The recommendation led the SITE Program to select the Demode Road Superfund Site for the demonstration of the Shirco Pilot-Scale Infrared Incineration System. Thermal destruction ultimately was chosen in the Record of Decision (ROD) for this site, which was signed on September 30, 1987.

During the period from November 2-13, 1987, Shirco Infrared Systems, Inc., Dallas, Texas, demonstrated the capability of its pilot-scale unit to treat 1,799 kg (3,967 lb), at test conditions, of the contaminated soil at the Demode Road site.

The Shirco Pilot-Scale Infrared Incineration System is enclosed in a single 45-ft trailer and is designed to treat wastes at a pilot-scale rate of one ton per day. A specific process description of the unit is presented in Section 4.1 of this report.

During the test period, a detailed sampling and analytical program as defined by an EPA Category II Quality Assurance Project Plan (QAPP), included in Appendix C, Volume II, was conducted.

1.2 PROGRAM OBJECTIVES

The major objectives of this demonstration were to determine the following:

- DRE levels for PCBs and the presence of PICs in the stack gas. The regulatory standards are 99.99% DRE under the Resource Conservation and Recovery Act (RCRA) and 99.9999% DRE under the Toxic Substances and Control Act (TSCA).
- Level of hydrogen chloride (HCl) and particulates in the stack gas. The RCRA standard for HCl in the stack gas is 1.8 kg/hr (4 lb/hr) or 99 wt% HCl removal efficiency. The RCRA standard for particulate emissions in the stack gas is 180 mg/dscm (0.08 gr/dscf).
- Level of residual PCBs in the furnace ash at normal and varied operating conditions.
- Mobility of heavy metals, particularly lead, in the furnace ash as compared to the feed.
- Mobility of heavy metals in the furnace ash as compared to the RCRA Extraction Procedure Toxicity (EP Tox) Characteristic (as measured by the EP Tox test) and the

proposed toxicity characteristic (as measured by the Toxicity Characteristic Leaching Procedure (TCLP)).

- Level of residual heavy metals and organic compounds, and other physical and chemical characteristics in the scrubber water discharged from the unit.

- The operating conditions that reduce energy consumption without decreasing soil decontamination effectiveness.

- Effect of varying operating conditions on residual levels of heavy metals and organics in the furnace ash versus the levels in the feed.

- Adherence of the quality assurance (QA) procedures to the requirements of the RREL approved QA Project Plan (Category II), as defined by the Document No. PA QAPP-0007-GFS, "Preparation Aid for HWERL's Category II Quality Assurance Project Plans", June, 1987.

SECTION 2

EXECUTIVE SUMMARY

INTRODUCTION

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), the Environmental Protection Agency's Office of Research and Development (ORD) and Solid Waste and Emergency Response (OSWER) have established a formal program to accelerate the development, demonstration, and use of new or innovative technologies as alternatives to current containment systems for hazardous wastes. This new program is called Superfund Innovative Technology Evaluation or SITE. The principal goal of the SITE program is to demonstrate new technologies in the field and develop reliable economics and performance information.

The SITE program demonstration of the Shirco Pilot-Scale Infrared Incineration System for thermal treatment developed by Shirco Infrared Systems, Inc. of Dallas, Texas, was conducted at the Demode Road Superfund Site in Rose Township, Michigan. The Demode Road site is a 12-acre waste site previously used to bury, dump, and store industrial wastes such as paint sludges, solvents, and other wastes containing PCBs, oils and greases, phenols, and heavy metals. PCBs and lead are the principal contaminants in the soil used for the test of the Infrared System.

The test was conducted from November 2-13, 1987 and treated 1,799 kg (3,967 lb) of contaminated soil under various test conditions. The major objectives of this demonstration were to determine the following:

o DRE levels for PCBs and the presence of PICs in the stack gas. The regulatory standards are 99.99% DRE under the Resource Conservation and Recovery Act (RCRA) and 99.9999% DRE under the Toxic Substances and Control Act (TSCA).

o Level of hydrogen chloride (HCl) and particulates in the stack gas. The RCRA standard for HCl in the stack gas is 1.8 kg/hr (4 lb/hr) or 99 wt% HCl removal efficiency. The RCRA standard for particulate emissions in the stack gas is 180 mg/dscm (0.08 gr/dscf).

o Level of residual PCBs in the furnace ash at normal and varied operating conditions.

o Mobility of heavy metals, particularly lead, in the furnace ash as compared to the feed.

o Mobility of heavy metals in the furnace ash as compared to the RCRA Extraction Procedure Toxicity (EP Tox)

Characteristic (as measured by the EP Tox test) and the proposed toxicity characteristic (as measured by the Toxicity Characteristic Leaching Procedure (TCLP)).

- Level of residual heavy metals and organic compounds, and other physical and chemical characteristics in the scrubber water discharged from the unit.
- The operating conditions that reduce energy consumption without decreasing soil decontamination effectiveness.
- Effect of varying operating conditions on residual levels of heavy metals and organics in the furnace ash versus the levels in the feed.
- Adherence of the quality assurance (QA) procedures to the requirements of the RREL approved QA Project Plan (Category II), as defined by the Document No. PA QAPP-0007-GFS, "Preparation Aid for HWERL's Category II Quality Assurance Project Plans", June, 1987.

FEED PREPARATION

The demonstration test used soil from an area of the site that was highly contaminated with PCBs and lead, as determined in the original remedial investigations performed at the site. Pretest sampling and analysis further identified those sectors within the area most highly contaminated with PCBs and lead for excavation. Other organic and heavy metals were also present in these sectors. Soil from these sectors to be used as feed for the test was excavated and mixed into a pile using a front-end loader, and then screened to remove aggregate and debris greater than one inch in diameter. The screened soil was drummed and transferred to a designated zone adjacent to the test unit. Two drums of soil were blended with 3 wt% fuel oil to be used for several of the test runs to investigate the effect of increased feed heating value on overall unit performance and energy consumption at varying operating conditions.

PROCESS DESCRIPTION

The Shirco Pilot-Scale Infrared Incineration System consists of a waste feed system, an (electric) infrared primary combustion chamber, a supplemental propane-fired secondary combustion chamber, a venturi scrubber emissions control system, an exhaust system, and a data collection and control system, all enclosed in a 45-ft trailer. The system process flow and the overall 250 ft x 100 ft test site layout are presented schematically in Figures 1 and 2, respectively.

During the test, the feed material was transferred from the drums to pails, weighed, and then fed manually to a hopper

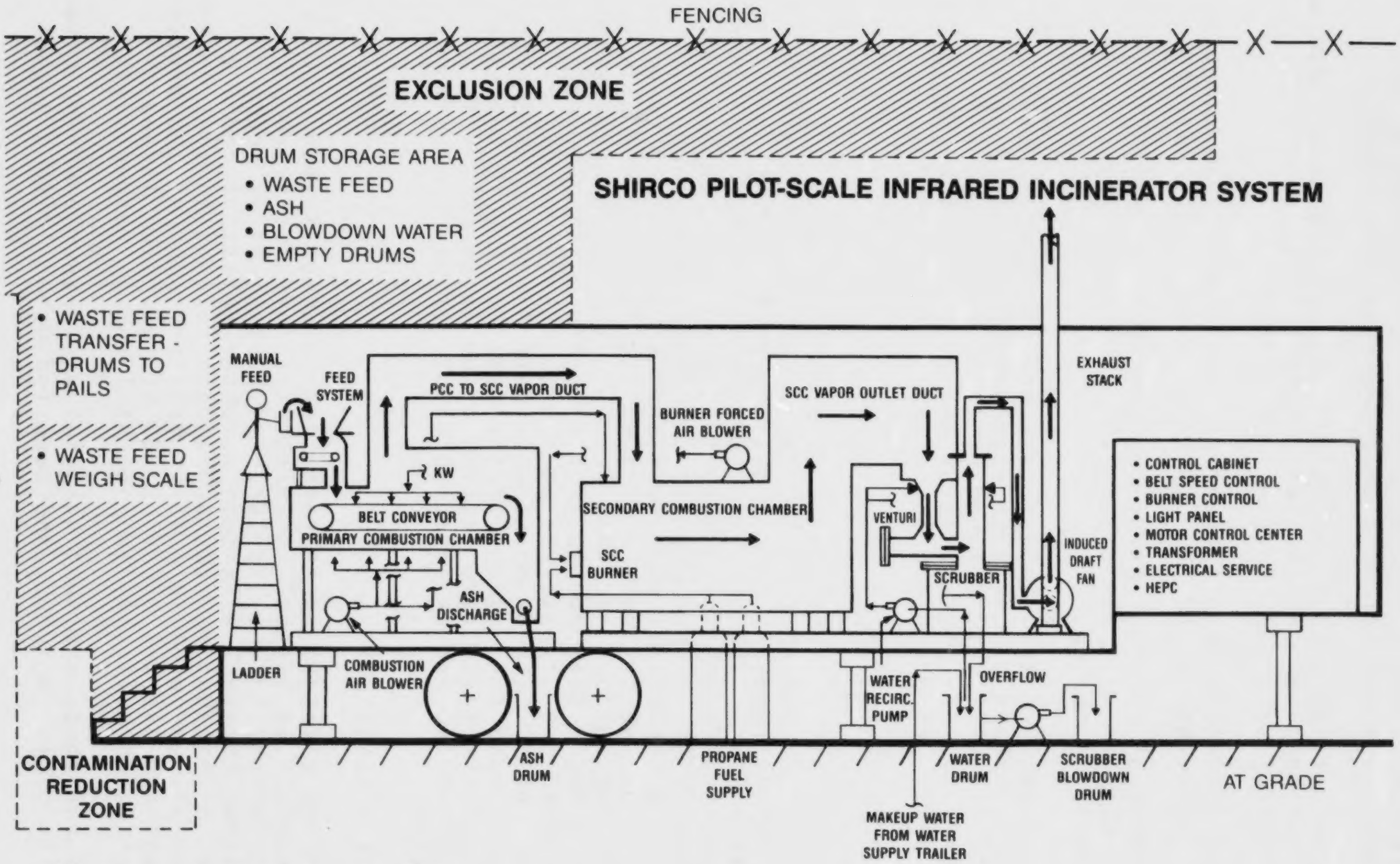

Figure 1. System process flow.

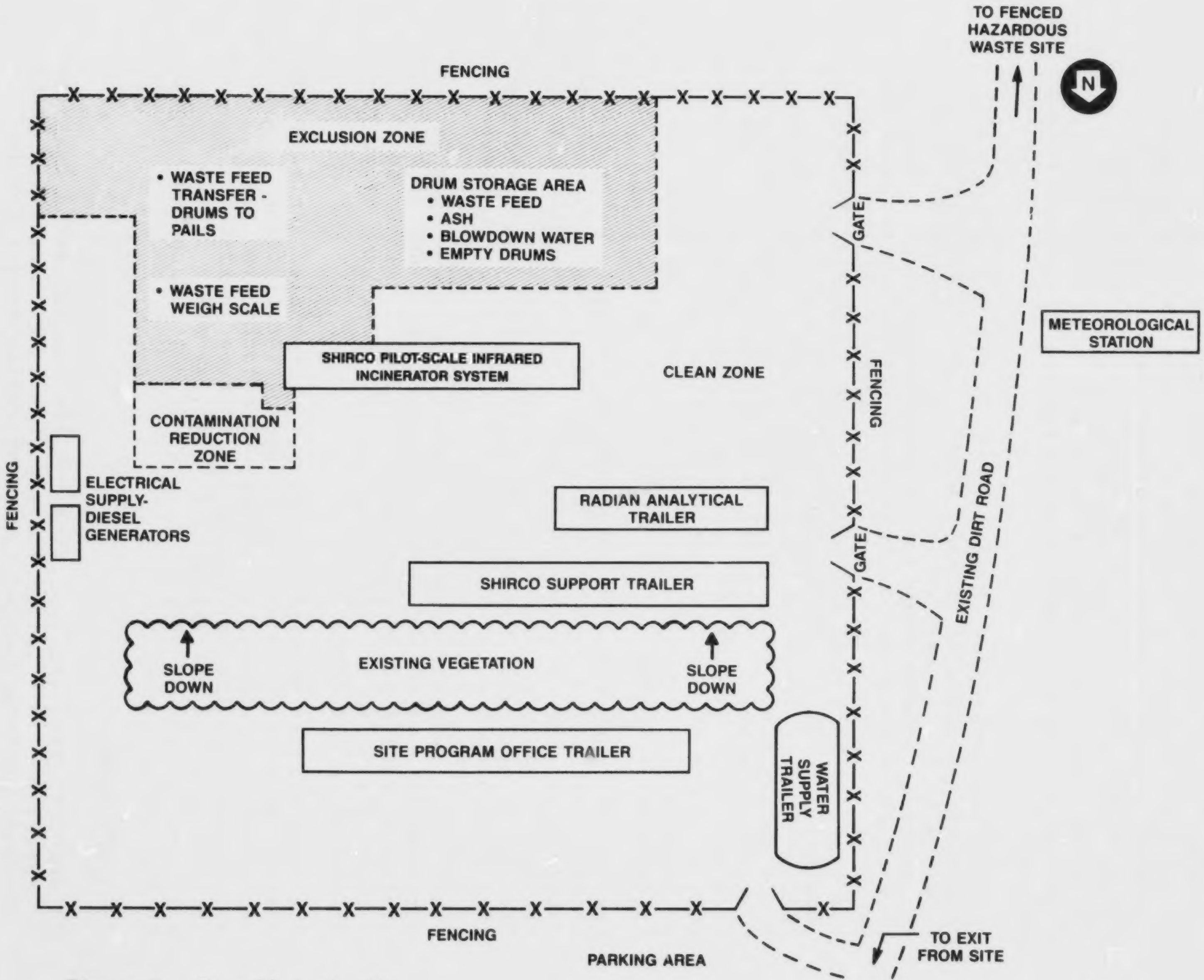

Figure 2. Overall test site.

mounted over a metering conveyor belt. The waste was fed at a controlled rate through a sealed feed chute onto the incinerator conveyor (a tightly woven wire belt which moved the waste material through the primary combustion chamber). The conveyor belt speed can be adjusted to achieve feed residence times in the PCC from 6 to 60 min. Typically residence times range from 10 to 25 min. The depth of the waste on the conveyor belt ranged from one to one and a half inches.

The primary combustion chamber (PCC) is a rectangular box insulated by layers of ceramic fiber. Combustion air is supplied to the primary combustion chamber through a series of air ports at points along the length of the chamber. The gas flow in the incinerator is countercurrent to the conveyed feed material. Electric infrared heating elements installed above the conveyor belt heat the waste to the designated temperature (nominally 1,600°F), which results in desorption or incineration of organic contaminants from the feed. Rotary rakes gently turn the material to ensure adequate mixing and complete desorption. When the thermally treated soil, now referred to as furnace ash, reaches the discharge end of the PCC, it drops off the belt through a chute and into an enclosed hopper and discharge storage drum. The drums of furnace ash are then stored for final disposal.

Exhaust gas containing the desorbed contaminants exits the primary combustion chamber into a secondary combustion chamber (SCC) or afterburner, where a propane-fired burner combusts residual organic compounds into CO_2, CO, HCl, and H_2O. The SCC is typically operated at 2,200°F and a gas residence time exceeding 2 sec. Secondary air is supplied to ensure adequate excess oxygen levels for complete combustion. Exhaust gas from the secondary combustion chamber then is quenched by a water-fed venturi scrubber emissions control system to remove particulate matter and acid gases. An induced draft fan transfers the gas to the exhaust stack for discharge to the atmosphere.

The same trailer housing the thermal system also contains the control panel for the main unit, and data collection indicators and recorders. Safety interlocks also are integrated into the tailor-mounted unit to automatically correct abnormal operating conditions, maintain system performance, and if necessary, shut down feed and heat input to the unit.

TEST PROCEDURE

In order to meet the objectives of the demonstration test (see Introduction), a total of 17 test runs were conducted. Three runs were performed under design operating conditions to assess overall unit operation and system performance (Phase I), and 14 runs were conducted under varying operational parameters to evaluate their effect on system performance and energy consumption (Phase II).

The Phase I runs were conducted at 1,600°F PCC temperature, a 2,200°F SCC temperature, and a PCC residence time of 20 min. Each of the three runs was sufficiently long (six to ten hours) to gather a large enough sample of stack gas to analyze it for PCBs. An additional run was conducted at the same operating conditions to obtain specific stack samples that had not been successfully collected during two of the previous runs.

The Phase II runs were conducted for approximately one hour under varied operating conditions that included the PCC temperature (900, 1,200, 1,400, and 1,600°F), SCC temperature (1,800 and 2,200°F), PCC feed residence time (10, 15, 20, and 25 minutes), and PCC combustion air flow (on, off to simulate oxidizing or non-oxidizing (pyrolytic) PCC atmosphere).

For the Phase I runs, samples were taken of the feed, scrubber makeup water, furnace ash, scrubber water, and scrubber solids. These streams were analyzed for PCBs, dioxins and furans, metals, organics, and other physical and chemical properties and components specific to the characterization of each sampled matrix. In addition, the EP Tox and TCLP leaching tests were performed on these sampled streams (exclusive of scrubber water makeup) and the extracts were evaluated for metals. Samples were also taken of the upwind and downwind ambient air, PCC offgas, and stack gas. Ambient air upwind and downwind of the unit was monitored for PCBs and heavy metals by high volume samplers. For the stack gas and PCC offgas, several sampling methods were employed, including an EPA Method 5 for particulate matter (and subsequent metals analysis of particulates) and hydrochloric acid; a Source Assessment Sampling System (SASS) for semivolatile organic pollutants, PCBs, dioxins and furans; a Volatile Organic Sampling Train (VOST) for volatile organic pollutants; a Modified Method 5 for soluble chromium; continuous emission monitoring for oxygen, carbon dioxide, carbon monoxide, oxides of nitrogen, and total hydrocarbons; and an experimental method for vaporous lead emissions in the PCC offgas.

For the Phase II runs, samples were taken of the feed, furnace ash, scrubber water, scrubber solids, PCC offgas, stack gas, and upwind and downwind ambient air. EPA Method 5 was used again to sample stack gas and PCC offgas but was analyzed only for particulate matter. In addition, throughout the Phase II tests, the stack gas and PCC offgas were continuously monitored for oxygen, carbon dioxide, carbon monoxide, oxides of nitrogen, and total hydrocarbons. All of the remaining sampled streams were analyzed for PCBs, dioxins and furans, metals, and other physical and chemical properties and components specific to the characterization of each sampled matrix. In addition, the EP Tox and TCLP leaching tests were performed on these samples and the extracts were evaluated for metals.

All of the sampling and analytical work was conducted in accordance with QA/QC Category II and include data quality credibility statements for the precision and accuracy of the data reported.

RESULTS AND DISCUSSION

A detailed summary of the SITE demonstration test results is presented in Table 1. Based on the test objectives outlined in the Introduction, the following results were obtained.

o Characteristics of the Feed

Based on data from the previous remedial investigation of the site, a specific area within the site was identified with the highest concentrations of both PCBs and lead, the major soil contaminants of concern. The remedial investigation also described the soil as a dry, brown, sandy, and silty clay topsoil which upon excavation proved to be an accurate observation. Subsequent pretest sampling and analysis of the specific area of the site identified particular sectors with the highest contamination of PCBs and lead. A composite sample of all the sectors within the area indicated a 7.8 pH, 9.0 wt.% moisture, 81 wt.% ash, less than 1000 Btu/lb high heating value, and a 0.95 g/cc density. The composite sample contained 570 ppm of total PCBs and 580 ppm lead (elemental lead after digestion and conversion to inorganic form). A composite sample of the 10 sectors chosen for excavation contained 626 ppm PCBs, 560 ppm of lead, 55 ppb of tetrachlorodibenzo-p-dioxin (TCDD), and 4.2 ppb of tetrachlorodibenzofuran (TCDF). Once the feed excavation was begun, it became evident that the front-end loader could not confine its large-scale activities to the 10 specific sectors and an area comprising 14 specific sectors was excavated for the unit's feed source.

Table 1 summarizes the PCB and lead contaminant concentrations measured in the soil from the composite of the grab samples of feed taken during each of the test runs. In addition to lead, where concentrations ranged from 290 to 3000 ppm and averaged 778 ppm, several other metals were present at average concentrations exceeding 50

TABLE 1. SITE DEMONSTRATION TEST RESULTS SUMMARY

Operating Conditions PCC		Waste Feed Characteristics				Furnace Ash Characteristics			
Temp. °F	Residence time min.	PCB ppm	Pb ppm	EP Tox (Pb) ppm	TCLP (Pb) ppm	PCB ppm	(Pb) ppm	EP Tox (Pb) ppm	TCLP (Pb) ppm
900(a,b)	20	327	590	0.29	0.81	2.079	1000	0.38	2.90
900(b)	20	20.2	660	0.67	0.88	3.396	1400	0.89	6.20
900(b)	25	367	290	0.32	7.00	0.168	860	0.88	3.80
1200	20	297	640	0.05	0.56	0.115(d)	1100	4.10	1.60
1200	15	27.6	870	0.20	0.44	0.077	1000	0.38	3.60
1200(b)	25	456	590	0.12	0.53	0.108(d)	1200	0.14	0.05
1200(b)	20	669	610	0.20	0.71	0.066(d)	1200	0.06 4.90(g)	4.10 2.80(g)
1200(b)	15	602	470	0.18	0.53	0.025(d)	2000	(h)	(h)
1200(a,b)	15	309	370	0.21	0.96	0.066(d)	1000	0.46	0.82
1400	20	56.0	740	0.07	0.89	0.087(d)	1600	ND	0.15
1600	20	10.2	3000	0.15	0.67	0.037	1100	0.05	ND
1600	20	35.2	1400	0.20	0.35	0.112	1300	ND	ND
1600	20	20.4	550	0.23	1.30	0.003	1100	0.13	0.05
1600	20	(f)	1100	0.14	0.49	(f)	420	0.28	1.80
1600	10	391	620	0.25	0.73	0.045(d)	1700	ND	1.00
1600(a)	15	451	620	ND	0.66	0.117(d)	840	0.43	0.17
1600(a)	15(c)	271	390	0.53	1.80	0.004	1500	0.27	0.23
1600(a,b)	15	311	500	0.07 3.00(g)	0.55 1.40(g)	0.061(d)	800	1.10	2.40

(a)	Waste feed blended with 3 wt.% fuel oil.
(b)	Non-oxidizing atmosphere.
(c)	PCC bed depth at 1 inch. All other tests at 1 1/2 inches.
(d)	PCB levels below analytical detection limits. Total shown is sum of detectable limits indicated in analyses.
(e)	ND - nondetectable value.
(f)	Run was conducted to makeup for incomplete semivolatile organics, PCDD/PCDF, soluble chromium and stack gas particulate samplings on other runs.
(g)	Data from additional EP Tox and TCLP tests.
(h)	ND due to broken sample container.

ppm including barium (591 ppm), zinc (301 ppm), and chromium (85 ppm). Total PCBs concentration ranged from 10.2 to 669 ppm and averaged 272 ppm.

Several samples of the feed contained small quantities of TCDFs ranging from 0.04 to 0.1 ppb. Volatile and semivolatile organic compounds including methyl ethyl ketone, trichloroethene, and bis(2-ethylhexyl)phthalate were measured in feed samples at concentrations less than 50 ppm. Methyl ethyl ketone and trichloroethene were also detected in solvent blanks and are attributed to analytical laboratory contamination.

o Characteristics of the of Furnace Ash

Table 1 summarizes the PCB and lead contaminant concentrations measured in the furnace ash from the composited grab samples taken at the conclusion of each test run. In addition to lead, where concentrations ranged from 420 to 2000 ppm and averaged 1173 ppm, several other metals were present at average concentrations exceeding 50 ppm including barium (1061 ppm), zinc (410 ppm), and chromium (81 ppm). Total PCBs concentration ranged from 0.004 to 3.396 ppm. Two samples of furnace ash contained 0.07 and 0.3 ppb of TCDF during two runs conducted at a 900°F PCC operating temperature; the normal PCC operating temperature is 1600°F. These runs were also conducted without the input of PCC combustion air to simulate non-oxidizing or pyrolytic combustion conditions. The low PCC temperature and pyrolytic environment could have led to the incomplete desorption or incineration of TCDF present in the feed or to the production of TCDF from the incomplete combustion of PCBs in the feed. Volatile compounds including methylene chloride, methyl ethyl ketone, tetrachloroethene, and trichloroethene were also measured in the furnace ash samples in concentrations ranging from 3.9 to 64 ppm with one sample containing 980 ppm of methylene chloride. Methyl ethyl ketone and trichloroethene were also detected in solvent blanks and methylene chloride is commonly employed in laboratory procedures; therefore these compounds may be products of incomplete combustion and/or the result of laboratory contamination.

o Residual PCBs in Furnace Ash

During the demonstration test, a total of 17 runs were conducted at varying operating conditions. In addition to the DRE levels, which are an indication of the performance of the Shirco Pilot-Scale Infrared Incineration System and its ability to meet RCRA and/or TSCA regulatory standards, the reduction of PCB concentration from the feed to the furnace ash is also a measure of the unit's ability to effectively destroy PCBs and produce a furnace ash with a PCB concentration below the TSCA guidance level of 2 ppm.

Based on the data presented in Table 1, two samples of furnace ash exceeded the TSCA guidance levels and contained 3.396 and 2.079 ppm of total residual PCBs. The samples were produced during two runs conducted at a 900°F PCC operating temperature (20 minutes residence time), which is significantly lower than the normal PCC operating temperature of 1600°F. These runs were also conducted without the input of PCC combustion air to simulate non-oxidizing or pyrolytic combustion conditions. At this low PCC temperature and pyrolytic condition, these higher total residual PCB levels in the furnace ash may be the result of the incomplete combustion of PCBs in the feed. This is further substantiated by the residual TCDF present in the furnace ash samples from these same two runs, as discussed previously. The remaining runs conducted at 1200, 1400, and 1600°F resulted in total residual PCB concentrations in the furnace ash ranging from 0.003 to 0.117 ppm. A third run, which was conducted at a 900°F PCC operating temperature but with an increased PCC residence time of 25 minutes resulted in a total furnace ash PCB concentration of 0.168 ppm with no detectable TCDF. It is possible that the increased residence time in the PCC may have offset the low 900°F PCC operating temperature and provided the additional processing time for the satisfactory destruction of the PCBs in the feed.

- Mobility of Heavy Metals - Feed and Furnace Ash

In order to determine whether heavy metals, particularly lead, would leach from the furnace ash produced in the Shirco Pilot-Scale Infrared Incineration System, EP Tox and TCLP tests were conducted to determine the mobility of heavy metals from the furnace ash as compared to the feed.

The initial EP Tox analyses for lead in the leachate ranged from 0.05 to 0.67 ppm for the feed and 0.05 to 4.1 ppm for the furnace ash. The initial TCLP analyses ranged from 0.35 to 1.80 ppm (with one sample at 7.0 ppm) for the feed and 0.05 to 4.1 ppm (with one sample at 6.2 ppm) for the furnace ash.

A comparison of the EP Tox and TCLP analyses conducted on the furnace ash and the feed do not show any trend or evidence that indicate reduced mobility of lead from the furnace ash versus the feed as a result of the thermal treatment. The comparison did reveal that the concentrations of lead in the TCLP leachates from both the feed and the furnace ash were consistently higher than the corresponding EP Tox tests on the same samples.

When several samples were retested to verify the results, the concentrations of lead in the EP Tox leachates (4.9 ppm feed, 3.0 ppm furnace ash) were higher than during the initial tests and, in direct reversal to the original data, exceeding corresponding TCLP leachate concentrations (2.8 ppm feed, 1.4 ppm furnace ash). The results of the retest again did not indicate reduced mobility of lead from the furnace ash versus the feed as a result of the thermal treatment.

- Mobility of Heavy Metals - EP Tox and Proposed TCLP Toxicity Characteristic Standards

  EP Tox and TCLP tests were conducted on the feed, furnace ash, scrubber water, and scrubber solids. All of the results were below the EP Tox and proposed TCLP toxicity characteristic standards of 5 ppm arsenic, 100 ppm barium, 1 ppm cadmium, 5 ppm chromium, 5 ppm lead, 0.2 ppm mercury, 1 ppm selenium, and 5 ppm silver except for one feed sample at 7.0 ppm lead (TCLP) and one furnace ash sample at 6.2 ppm lead (TCLP). A comparison of the EP Tox and TCLP analyses on all the sampled streams to the abovementioned standards do not show any trend or evidence that indicate reduced mobility of heavy metals as a result of the thermal treatment.

- Destruction and Removal Efficiency (DRE) of PCBs

  The DRE of PCBs for the first three runs (Phase I) is greater than 99.99%. In contrast, the regulatory standard for incineration under the RCRA is 99.99% DRE and under TSCA is 99.9999% DRE. The low PCB concentrations in the feed resulted in PCB levels in the stack gas that were less than the analytical detection limits for two of the runs. Therefore for these runs, DRE is calculated based on the sum of the detection limits of the PCB congenors in order to compare the DRE for the runs on the same basis. Stack gas measurements conducted during the third run did detect trichlorobiphenyl and tetrachlorobiphenyl congenors and a DRE is shown based on this measurement. The less rigorous sampling in Phase II of the test was not designed to allow calculation of DRE.

- Other Organic Stack Gas and PCC Offgas Emissions

  Several volatile and semivolatile organic compounds were detected in the stack gas at concentrations less than 100 ppb and established standards for direct inhalation. Low levels of several phthalate compounds were also detected in blank samples and may be traced to contamination from plastic components in the process, sampling equipment, or laboratory apparatus. Several volatile organic compounds including benzene and toluene were detected in the stack gas and the scrubber makeup water and may be attributable to contamination from the makeup water although PIC formation is a possibility. Other volatile and semivolatile organic compounds, which probably represent PICs, were detected. They include halomethanes, chlorinated species including chlorobenzene and methylene chloride, other volatile organics including xylenes, styrene and ethylbenzene, oxygenated hydrocarbons including acetone and acrolein, carbon disulfide, and p-chlor-m-cresol. Dioxins and furans were not detected in the stack gas samples.

The majority of the organic compounds present in the PCC off gas samples at levels less than 500 ppb were also present in the stack gas. The additional destruction of organics that take place in the SCC and emissions scrubbing system reduced the concentration of these organic compounds in the corresponding stack gas samples.

o Acid Gas Removal

During the Phase I Runs 1-3, HCl emissions ranged from 0.181 to 0.998 g/hr, which were significantly below the RCRA performance standard of 1800 g/hr that would require a 99 wt.% HCl removal efficiency. HCl removal efficiencies ranged from 97.23 to 99.35 wt.%. Acid gas removal was not measured in Phase II.

o Particulate Emissions

Particulate emissions were measured throughout the test and ranged from 7 to 68 mg/dscm, well below the RCRA standard of 180 mg/dscm.

o Analysis of Scrubber Makeup Water, Scrubber Water, and Scrubber Solids

Scrubber makeup water was transported to the site in a tank truck that may have contained some residual contamination prior to fill up. Samples of scrubber makeup water were taken at the end of each run. No PCBs, dioxins, furans, or semivolatile organic compounds were detected. Several volatile organics including benzene, toluene, and trichloroethene were measured at concentrations less than 15 ppm. The concentrations of heavy metals were all less than 0.2 ppm.

Samples of the water recirculation through the venturi scrubber system, referred to as scrubber water, were also taken at the end of each run. PCB concentrations were less than 200 ppt and no dioxins, furans, or semivolatile organic compounds were detected Small quantities of benzene (2 ppm) and toluene (5.7 to 11 ppm) were measured in several of the samples and are attributable to the similar contaminants in the scrubber makeup water. The concentrations of heavy metals in the scrubber water were all less than 1 ppm except for barium, which ranged from 0.2 to 2.2 ppm, and lead, which ranged from 0.12 to 1.8 ppm.

Insufficient quantities of scrubber solids in the scrubber water were available for analysis.

- Overall Disposition of Metals

Total metals analyses of the feed, furnace ash, PCC offgas and stack gas particulates, scrubber makeup water, scrubber water, and scrubber solids showed that the majority of the detectable metals, including lead, that entered the unit with the feed remained in the furnace ash. An overall mass balance of lead through the unit was calculated based on the analysis of lead in the samples, the measured feed rate as weighed during the runs' operating periods, the calculated furnace ash flow rate based on the ultimate analysis of ash in the feed sample, and the measured particle mass and gas volume obtained from the gas' EPA Method 5 sampling trains. Phase I results indicate an average lead mass flow rate of 28.3 g/hr in the feed, 37.0 g/hr in the furnace ash, 0.206 g/hr in the PCC offgas particulates, and 0.109 g/hr in the stack gas particulates. The quantity of lead leaving the unit with scrubber water effluent is approximately 0.204 g/hr based on the maximum measured concentration of 1.8 ppm lead in the scrubber water and an overall approximate water flow rate of 30 gph. The PCC offgas particulates sampled during the Phase I runs contained an average of 5364 ppm of lead as compared to stack gas particulates, which contained an average of 15,830 ppm of lead. By contrast, the average concentration of lead in the feed was 1550 ppm. Although the concentration of lead in the particulate matter increases as the process flow progresses through the unit, the actual mass flow of lead decreases as the gas stream is cooled and treated through the emissions control system.

For the Phase I runs sampling and analysis procedures were conducted to evaluate vaporous lead concentrations in the PCC offgas and soluble chromium concentrations in the PCC offgas and stack gas particulates. The special sampling for vapor phase lead and soluble chromium were unable to detect any of either metal at levels less than 2.7 ppb and 264 ppb, respectively; therefore the evaluations were inconclusive.

Other heavy metals, particularly barium and zinc, with average concentrations exceeding 100 ppm in the feed (barium 591 ppm, zinc 301 ppm) were also present in high concentrations, relative to other heavy metals, in the furnace ash (barium 1061 ppm, zinc 410 ppm) and scrubber water (barium 0.8 ppm, zinc 0.3 ppm).

- Optimum Operating Conditions

Phase II was designed to examine the effect on energy consumption and changes in the residual levels of heavy metals and organics in the furnace ash versus the levels in the feed by varying operating conditions.

Based on the data obtained an analysis was conducted to compare energy consumption in the unit at operating conditions that did not affect the performance of the unit. A reduction in the PCC operating temperature from 1600°F to 1200°F reduced the average PCC power usage 48% from 0.2294 to 0.1200 kwhr/lb feed. A reduction in the SCC operating temperature from 2200°F to 1800°F reduced the average propane fuel consumption by 51% from 3997 to 1952 Btu/lb feed. The use of 3 wt.% fuel oil to supplement the fuel value of the feed further decreased PCC power usage by 26 to 67% at PCC operating temperatures of 1600°F and 1200°F, respectively, with accompanying increases in overall feed rate of 32% and 26%. The costs for fuel oil and its attendant facilities still must be examined for specific applications to determine the cost effectiveness of a fuel oil additive to the waste feed.

As discussed in previous sections the results did not provide any trend or change in the residual levels of the heavy metals and organics in the furnace ash versus the levels in the feed as the operating conditions were varied and PCC operating temperatures were maintained at 1200 to 1600°F. At an abnormally low PCC operating temperature of 900°F, without the input of combustion air to simulate non-oxidizing or pyrolytic combustion conditions, total PCB and TCDF concentrations in the furnace ash increased. The increases may indicate that these PCC conditions led to incomplete desorption or incineration of PCB and TCDF and to the production of TCDF from the incomplete combustion of PCBs in the feed.

- QA Summary

The Phase I and II runs had a well-defined quality assurance/quality control program to ensure the collection of accurate data. This program was developed as part of the test program preparation activities and was formalized in the RREL approved QA Project Plan (Category II). All of the sampling and analytical work was conducted in accordance with this QA Project Plan and the results include data quality credibility statements and information that confirm the satisfactory precision and accuracy of the data reported.

CONCLUSIONS

Based on the above data and discussion, the following conclusions can be made concerning the operation and performance of the Shirco Pilot-Scale Infrared Incineration System.

1. The PCC equipped with infrared heating rods reduced PCBs from an average of 272 ppm and a maximum of 669 ppm in the feed to less than 0.2 ppm PCBs in the furnace ash when PCC temperature was 1200°F or higher. Performance was well below the TSCA guidance level of 2 ppm of PCBs in treatment residuals.

2. The majority of the lead and other heavy metals present in the feed remained in the furnace ash, regardless of operating conditions. However, the scrubber water contained levels of lead and barium (up to 1.8 to 2.2 ppm, respectively), and metals also concentrated to some extent in the furnace ash. Both residual streams may require further treatment when metals are present in the feed. (See below).

3. Based on two leaching tests, the EP Tox and TCLP, the mobility of lead and other heavy metals was similar in the feed and the furnace ash, and there was no evidence that treatment affected metals leaching.

4. In most cases concentrations of metals in the extract of the furnace ash did not exceed their respective EP Tox and TCLP toxicity characteristic standards. The need for further treatment of the furnace ash to reduce or immobilize the metals is site specific, and will depend on the cleanup standards for the site.

5. The unit achieved DREs of PCBs greater than 99.99%, based on one actual calculation and in two cases on detection limits. PCB concentrations in the feed and analytical detection limits did not allow the demonstration of 99.9999% DRE required under TSCA. However, this unit achieved greater than 99.9999% DRE in other tests, and at this time at least one full-scale infrared system has demonstrated greater than 99.9999% DRE for PCBs and is permitted under TSCA to process PCB waste. The upcoming Applications Analysis Report will incorporate this additional data.

6. The unit achieved regulatory standards for acid gas removal and particulate emissions. These data apply to the operation and performance of the air pollution control system installed on this unit. Additional data on the performance of air pollution control systems on full-scale Shirco Infrared units will be discussed in the Applications Analysis Report.

7. Several semivolatile and volatile organic compounds measured in the stack gas in the parts per billion may be PICs. These levels are much lower than established standards for direct inhalation of these compounds.

8. The unit was able to reduce the PCBs in the feed using less power when fuel oil was added to the waste and when PCC temperature was reduced. The addition of fuel oil also increased the feed rate. Cost savings in specific applications will depend on local fuel and electrical costs, and a minimum PCC temperature must be maintained to avoid inadequate desorption of the organics in the feed and the production of PICs.

SECTION 3

PROCESS DESCRIPTION

3.1 GENERAL PROCESS DESCRIPTION

Contaminated soils at the Demode Road Superfund Site were incinerated in the Shirco Pilot-Scale Infrared Incineration System designed and manufactured by Shirco Infrared Systems, Inc. of Dallas, Texas. The system consists of a waste feed system, infrared primary combustion chamber (PCC), supplemental propane-fired secondary combustion chamber (SCC), venturi scrubber emissions control system, exhaust system, and data collection and control system all enclosed in a 45-ft trailer. The system process flow is presented in Figure 1 and the overall 250x100-ft test site layout is presented schematically in Figure 2.

The waste feed material is fed manually to a hopper mounted over a metering conveyor belt. This metering conveyor belt is synchronized with the primary combustion chamber conveyor to control the material feedrate through a sealed feed chute to the primary combustion chamber.

The incinerator conveyor, a tightly woven wire belt, moves the waste material through the insulated heating modules of the primary combustion chamber. The waste material is heated by electric infrared heating elements and contaminant desorption from the solid waste feed and subsequent volatilization of the organic contaminants occurs. Rotary rakes gently turn the material to ensure adequate mixing and contact with the heated chamber environment. When the combusted feed residual, now furnace ash, reaches the discharge end of the furnace, it drops off the belt through a chute and into an enclosed hopper and discharge storage drum. Combustion air is supplied to the primary combustion chamber through a series of overfire air ports at points along the length of the chamber. The gas flow in the incinerator is countercurrent to the conveyed waste feed material.

Exhaust gas containing the desorbed contaminants exits the primary combustion chamber and passes to a secondary combustion chamber (afterburner) where a propane-fired burner provides the final thermal destruction of any residual organics. Secondary air is supplied to ensure adequate excess O_2 levels for complete combustion. Exhaust gas from the secondary combustion chamber then is quenched by a water-fed venturi scrubber emissions control system to remove particulate matter and acid gases. The gas then is transferred to the exhaust stack by an induced draft fan and discharged to the atmosphere.

The main unit controls and data collection indicators/recorders comprising the data collection and control system are housed in the system trailer. Safety interlocks also are integrated into the trailer-mounted unit to automatically correct abnormal unit operating conditions, maintain system performance, and, if necessary shut down waste feed and heat input to the unit.

3.2 DETAILED PROCESS DESCRIPTION

The Shirco Pilot-Scale Infrared Incineration System consists of the following major mechanical subsystems and components:

- Waste Feed System
- Primary Combustion Chamber (electrically heated)
- Secondary Combustion Chamber
- Emissions Control System
- Exhaust System
- Data Collection and Control System

Additional equipment was provided to support the unit during operation; this includes two diesel generator sets to meet electrical requirements and a water supply tank trailer for makeup water needs.

3.2.1 Waste Feed System

Up to 150 lb/hr of waste material (prescreened or preprocessed soils, solids, semi-solids, and sludges) is fed manually from 5-gal pails into a hopper mounted over a metering conveyor belt. The conveyor is shrouded and equipped with rubber skirts to minimize infiltration of air or escape of furnace gases. An adjustable guillotine-type gate is provided at the conveyor discharge. The gate distributes the material across the width of the metering belt and assists in furnace sealing. Final feed area sealing is provided by an additional adjustable knife gate in the feed chute into the primary combustion chamber. The metering conveyor belt is synchronized with the primary combustion chamber conveyor for control of the material feedrate.

3.2.2 Primary Combustion Chamber

The primary combustion chamber design and operation is unique to the Shirco technology. It is in this primary chamber that the waste material is brought to a specified operating temperature by electric infrared heating and conveyed through temperature-controlled zones at a predetermined rate. The primary combustion chamber provides the heat required for the initial contaminant desorption of organic contaminants from the solid waste feed. The majority of the metal contaminants remain in the furnace ash that exits the primary combustion chamber.

The primary combustion chamber is a rectangular box (length 9.75 ft, width 2.5 ft, height 6.58 ft) constructed of 0.25-in A36 carbon steel. It is insulated with ceramic fiber blanket insulation mounted on stainless steel studs and retained with ceramic fasteners. The insulation is manufactured by Carborundum Co. and consists of an 85% silica/15% alumina asbestos-free blend that can sustain a continuous surface temperature of 2400°F. The insulation is 7 in thick on the chamber top, sides, and end plates, and 5 in on the chamber bottom.

The material to be processed is conveyed through the furnace on a woven wire belt, at a bed depth ranging from 0.5 to 2 in, that is supported on high-temperature alloy shafts. The shafts are, in turn, supported by external flange-mounted bearings. A friction drive system is used to pull the belt through the furnace. The belt is woven (to a thickness of 0.25 in) from 16-gauge, Type-314 stainless steel. The belt speed is controlled via a constant speed motor/variable speed reducer, and can be adjusted to achieve waste material residence times of 6 to 60 min.

Infrared energy is provided by 18 transversely-mounted silicon carbide rod heating elements mounted on 3.07-in centers 8.75 in above the furnace belt. These 1.0-in OD (outside diameter) heating elements are manufactured by Carborundum Co., and are rated at 33.1 watts/in^2 of radiating surface with a maximum surface temperature of 2000°F. The primary chamber is divided into two temperature control zones, with six heating elements serving each zone. The temperature in each zone can be precisely regulated between 500°F and 1850°F. The maximum operating temperature of the primary chamber zones is 1900°F.

Four rotary rakes transversely-mounted on 1-ft centers gently turn the material on the belt, increasing exposure. The rotary rakes consist of L-shaped fingers (0.19-in OD Inconel 601) welded to Type-316 stainless steel shafts that rotate at a rate of 1.8 revolutions/in of belt travel. The shafts are synchronized with the belt speed through a chain and sprocket drive system.

Combustion air is supplied to the primary chamber through 16 1.0-in-diameter overfire air ports located 1.75-in above the belt surface in a single row of 8 ports on each side of the chamber. Combustion air flowrate and distribution to each group of four ports (two groups per chamber side) are controlled by manual gate valves. The combustion air blower is manufactured by New York Blower Co. and is rated at 185 scfm at a static pressure of 0.25-in water column (WC). The combustion air supply can be controlled to provide either oxidizing or reducing atmospheres.

Exhaust gas containing the desorbed organic contaminants and metal contaminants that did not remain in the furnace ash exits the primary combustion chamber and flows through the flue gas ductwork to the secondary combustion chamber.

3.2.3 Secondary Combustion Chamber

The secondary combustion chamber consists of a rectangular carbon steel box (length 11.0 ft, width 3.33 ft, height 3.33 ft) lined with 12-in Carborundum ceramic fiber blanket insulation on all interior walls. The insulation type is identical to that used in the primary chamber. The internal cross-sectional area of the chamber is 1.56 ft^2 and the internal volume is 28.9 ft^3. The unit is designed for 0-200% excess air operation with a maximum continuous operating temperature of 2300°F and a minimum residence time of 1.3 sec at a maximum actual gas flow of 830 acfm. At these operating conditions the secondary combustion chamber provides the final thermal destruction of the organic contaminants contained in the flue gas from the primary combustion chamber.

Supplemental fuel firing is supplied by a 375,000 Btu/hr propane burner manufactured by MAXON. The burner is equipped with a continuous pilot flame monitor, automatic fuel shutoff, and purge system interlocked with the secondary combustion chamber temperature sensor and manual fuel control valve. Combustion air supply to the burner is controlled by manually adjustable air registers.

Secondary combustion air (excess air) is supplied to the chamber through two 1-in-diameter ports located at the top of the chamber: they are directed at the interface of the burner flame pattern and the exhaust gas inlet flow. Secondary combustion air is supplied by the same fan that is used to supply the primary chamber combustion air. A splitter manifold with dampers at the fan outlet allows air distribution to both chambers. A manual gate valve adjusts the air flowrate to the secondary chamber.

3.2.4 Emissions Control System

The emissions control system consists of a venturi, scrubber, and droplet separator tower. Water is used as the scrubbing liquor. A lime slurry system is provided if acid gas neutralization is required. The venturi section and separator tower are each equipped with two water spray nozzles. The maximum-rated water flowrate is 2 gpm and 10 gpm to the venturi and separator tower, respectively. If an external water service of 25-30 psig and 15 gpm (minimum) is not available, a makeup water system is provided. The venturi section is equipped with a manually adjustable plumb bob to control gas phase pressure drop between 8 and 14 in WC and to effect maximum collection efficiency.

The scrubber is equipped with an integral 45-gal sump tank, external 50-gal holding tank, and recirculation pump for effluent handling and disposal. Makeup water is supplied from a water supply tank trailer, as required to account for evaporative losses. Total scrubber water blowdown is approximately 30-45 gal/day.

In addition to removing particulate, the scrubber cools the gases (incoming temperatures: 1000°F - 2300°F, depending on system configuration) to saturation temperature (usually about 180°F). Subcooling to a lower temperature can be performed if required, but this procedure consumes substantially more water than cooling to saturation temperature.

3.2.5 Exhaust System

An induced draft fan located downstream of the scrubber exhausts the scrubbed gas to the stack. The fan is manufactured by New York Blower Co. and is rated at 400 acfm at a static pressure of 14-in WC.

Exhaust gases are vented to the atmosphere through a 4.0-in ID stack, which extends through the roof of the trailer to an elevation of 23.6-in above grade (10 ft above trailer roof). The stack is equipped with two 3.0-in ID sampling ports. Access to the sampling ports is from the trailer roof.

3.2.6 Data Collection and Control System

The data collection and control system is designed to ensure that the various process operating conditions are maintained within the appropriate range for effective thermal treatment of the waste. Operating conditions are logged and compiled for future evaluation of the system's performance.

The Shirco Portable Demonstration Unit is fully instrumented to monitor the following process parameters:

- Temperature

  Primary Chamber:
    - Waste feed zone
    - Zone A1
    - Zone A2
    - Mid-zone
    - Zone B1
    - Zone B2
    - Exhaust gas
    - Ash discharge chute

Secondary Chamber:
  - Mid-chamber
  - Exhaust gas

Stack:
  - Exhaust gas

Recorder:
  - Six-point continuous stripchart

o Pressure

- Combustion air fan outlet
- Primary chamber draft
- Primary chamber exhaust draft
- Secondary chamber draft

- Secondary chamber combustion air
- Scrubber differential pressure
- Scrubbing liquor delivery pressure

o Liquor Flow

- Venturi scrubber liquor
- Separator tower liquor

o Exhaust Gas Analysis - Secondary Chamber Outlet

- Continuous O_2 monitor w/strip chart recorder
- Continuous CO monitor w/strip chart recorder
- Continuous CO_2 monitor w/strip chart recorder

o Master Control Panel

A master control panel contains the following devices for process data monitoring, recording, and control:

- Nine-point digital temperature display with rotary selector

- Six-point temperature strip chart recorder

- Primary chamber heat zone temperature controllers

- Primary chamber belt speed controller

- Annunciator

- Hand-Off-Auto switches for mechanical components.

- Three-point stripchart recorder for continuous emission monitors.

- Safety Interlocks

The Shirco system is equipped with safety interlocks to automatically correct abnormal incinerator operating conditions and maintain system performance. A description of the various interlock systems, corrective actions, and corrective action limits is presented in Table 2. The system also is equipped with an automatic waste feed cutoff system that will stop the waste feed conveyor belt motion in the event of low secondary chamber temperature. The cutoff limit for the waste feed shutdown control is adjustable.

TABLE 2. SAFETY INTERLOCK SYSTEMS

Interlock	Corrective action	Corrective action limit
Low primary chamber temperature	Infrared electric heating element power center on/ Waste feed belt stop	1600°F*
High primary chamber temperature	Infrared electric heating element power center off	1850°F
Low secondary chamber temperature	Propane burner on/ Waste feed belt stop	1800°F
High secondary chamber temperature	Propane burner off	2300°F
Emissions control during unit shutdown	Secondary chamber temperature maintained until primary chamber temperature drops below action limits	400°F
Excessive stack gas temperature	Alarm (manual adjustment of scrubbing liquor flow)	200°F
Low secondary chamber exhaust O_2	Alarm/Waste feed belt stop	4%
High secondary chamber exhaust CO	Alarm/Waste feed belt stop	100 ppm

* This was modified temporarily to allow the 900°F and 1200°F runs in Phase II testing.

SECTION 4

FIELD OPERATIONS DOCUMENTATION

4.1 PRETEST SAMPLING

The Demode Road Superfund Site is a 12-acre field, approximately 950x550 ft. By 1983, MDNR had removed drums of waste that were either buried or left on the ground and over 1,500 tons of contaminated soil. From 1984 to 1987 MDNR conducted a remedial investigation and feasibility study (RI/FS) to determine the nature and extent of the remaining contamination at the site and evaluate alternative cleanup technologies and methodologies. Based on the data presented in the RI/FS, a 10,000-sq ft area located in the southwestern section of the site was identified as having the highest soil PCB contamination. The remedial investigation described the soil as a dry, brown, sandy, and silty clay topsoil. This area was the focus of the pretest sampling phase, which was performed during the week of July 13, 1987 to identify the most highly contaminated waste feed source for the planned SITE test program. Figure 3 illustrates the entire Rose Township site and the specific excavation area as identified by the RI/FS.

The area was surveyed from existing survey markers, and a 12,100-sq ft grid with 100-sq ft sections was superimposed over the identified 10,000-sq ft site; the overlap ensured complete coverage of the area. Figure 4 illustrates the grid definition and specific sector ID numbers.

Based on the sampling grid the area was divided into thirty-six 100 sq ft sectors, S-1 through S-36. Four samples were taken in each sector (a total of 144 samples) and composited. These 36 soil samples were analyzed for PCB and lead content as presented in Table 3. A single composite sample of the 36 soil samples was analyzed for density, pH, moisture, ash, Btu value, and ultimate analysis, as presented in Table 4. A summary report of the pretest characterization analyses is presented in Appendix D, Volume II. These analyses confirmed significant PCB and lead contamination in sectors that were to be excavated to provide the waste feed source for the Shirco unit operation during the SITE demonstration. The analyses also characterized the waste feed source so that Shirco could define optimum unit operating conditions.

Ten of the 36 sectors were identified as areas that contained the maximum PCB- and/or lead-contaminated soils. Ten sectors

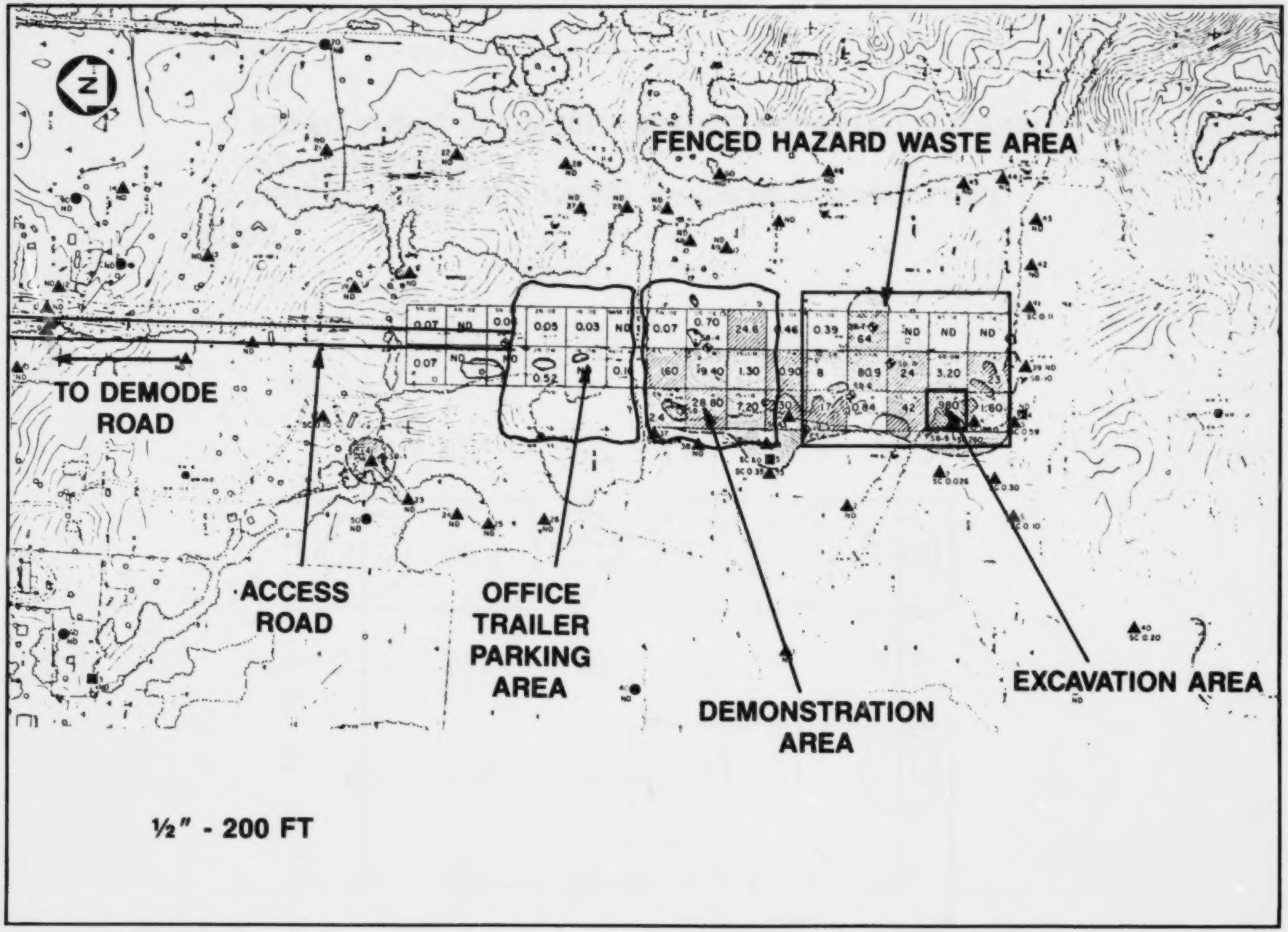

Figure 3. Demode Road Superfund Site.

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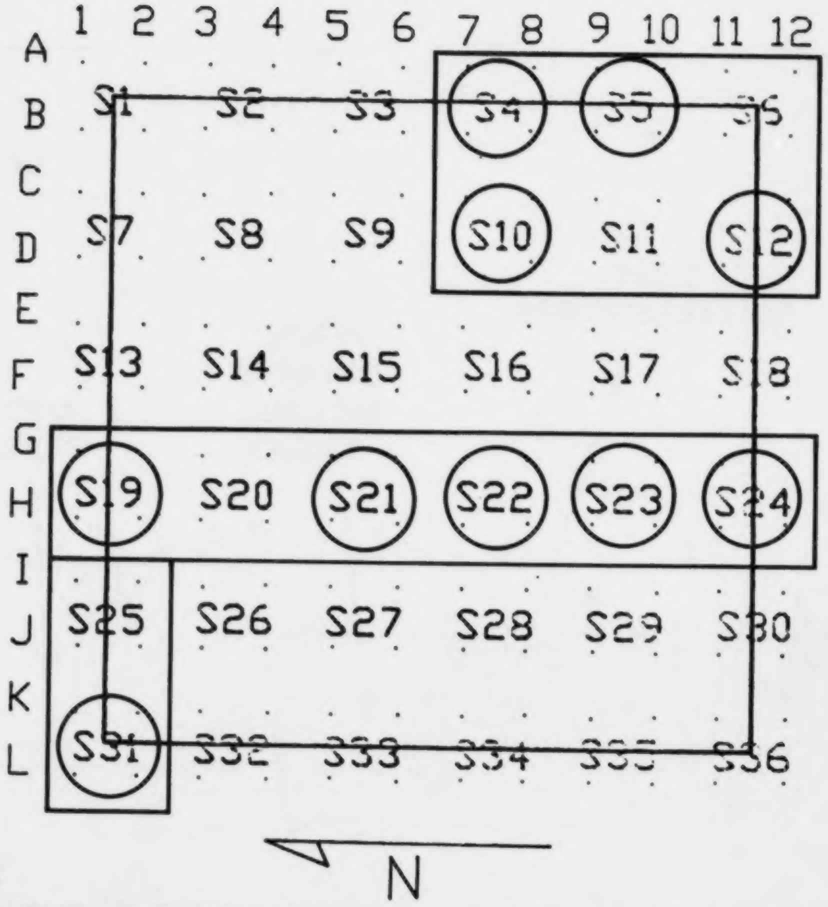

NOTES

1) CIRCLED SECTORS CONTAIN MAXIMUM PCB AND LEAD CONTAMINATION.

2) BOXED AREAS REPRESENT ACTUAL EXCAVATED SECTORS.

Figure 4. Pretest sampling grid.

TABLE 3. PRETEST SAMPLE ANALYSES

Grid sector sample ID No.	Total PCB content (ppm)	Total Lead content (ppm)
S1	70	100
S2	49	240
S3	169	310
S4 (a) (b)	1,270	370
S5 (a) (b)	29	740
S6 (b)	28	560
S7	132	400
S8	71	130
S9	232	240
S10 (a) (b)	1,230	330
S11 (b)	180	530
S12 (a) (b)	29	1,100
S13	200	450
S14	164	400
S15	610	220
S16	301	210
S17	360	340
S18	115	140
S19 (a) (b)	66	680
S20 (b)	47	440
S21 (a) (b)	1,550	240
S22 (a) (b)	1,300	160
S23 (a) (b)	1,410	200
S24 (a) (b)	1,120	180
S25 (b)	550	300
S26	128	240
S27	270	390
S28	262	93
S29	46	260
S30	290	180
S31 (a) (b)	1,020	460
S32	295	380
S33	28	-
S34	148	81
S35	103	110
S36	560	340

(a) Ten sectors designated as maximum PCB- and lead-contaminated. Calculated composite PCB and lead concentrations for these ten sectors is 902 ppm PCB and 446 ppm lead.

(b) Actual sectors that were field-excavated for waste feed supply to Shirco unit.

TABLE 4. PRETEST SAMPLE ANALYSES--COMPOSITE OF ALL SECTORS

Analytical parameter	
pH	7.8
Moisture, wt.%	9.0
Ash, wt.%	81
HHV, Btu/lb	<1000
Density, g/cc	0.95
Ultimate Analysis, wt.%	
C	2.27
H	0.84
N	ND/0.06*
O	4.06
Cl	0.15
S	0.032
P	0.042
PCB, ppm	570
Pb, ppm	580

* ND denotes not detected. Value shown is the detection limit.

were chosen to ensure that sufficient soil quantities would be excavated to meet the waste feed requirements of the Shirco unit during the 12 days of operation. A composite sample of these 10 sectors also was prepared and analyzed for PCBs, lead, polychlorinated dibenzo-p-dioxins, and dibenzofurans (PCDDs and PCDFs) as presented in Table 5. A summary report of these analyses is included in Appendix D, Volume II. The circled sectors in Figure 4 indicate the ten sectors that are discussed above.

Based on the pretest sampling and analyses discussed above, a comprehensive profile of the 10,000-sq ft area and its individual sectors was obtained. Tables 3, 4, and 5 present the analytical results of this pretest sampling program.

As detailed above, 10 sectors were chosen for excavation to a depth of 3- to 6-in as the waste feed supply for the SITE test program. Once the excavation activities began, it became evident that an exacting excavation of these 10 specific sectors was precluded because of the difficult terrain and the crude excavation ability of the front-end loader. The excavation areas then were defined more broadly as shown in Figure 4 by the boxed areas. Table 3 defines the originally specified 10 sectors and the more broadly defined areas that were actually excavated for the waste feed supply to the Shirco unit. Section 4.2.2 discusses the waste feed excavation activities that preceded the drumming and transport of the waste feed supply to the Shirco unit.

4.2 TEST SUMMARY

4.2.1 Pretest Operations

On 10/26/87 Shirco personnel arrived on site to observe feed screening and site preparation for the portable unit test. During the following week, the test site was leveled and covered with gravel fill. Following a significant rainfall that seriously deteriorated portions of the site, additional gravel fill and drainage to a sump hole were provided that resulted in a level and well-drained test site. The Shirco support trailer and two diesel power generators were delivered and set up for the test. The Shirco Portable Demonstration Unit arrived on site on 10/30/87. Demonstration supplies were unloaded, and the trailer was prepared for a public viewing at the Rose Township Hall on 10/31/87.

After a successful public showing at the Township Hall, the Portable Unit was taken back to the job site for setup. On 10/31/87 electrical power was hooked up, and scrubber water supply hose, control panel instruments, the ash discharge barrel, scrubber drain hose, the interior trailer lights, and the exhaust stack all were installed by Shirco personnel. The

TABLE 5. PRETEST SAMPLE ANALYSES--COMPOSITE OF TEN GRID SECTORS WITH MAXIMUM PCB AND LEAD CONTAMINATION

Composited grid sectors

S4
S5
S10
S12
S19
S21
S22
S23
S24
S31

	Actual composite analysis	Calculated composite analysis (Table 3)
Total PCDD, ppb	55	-
Total PCDF, ppb	4.2	-
Total PCB, ppm	626	902
Total Pb, ppm	560	446

overall test site layout is presented schematically in Figure 2. The furnace was heated to processing temperatures and then cooled to verify that all systems were operational.

A Health and Safety Plan was issued that defined the specific program organization and individual personnel responsible for specific health and safety and operating activities. The health and safety procedures also discussed site-specific and process-specific hazards, levels of protection, health and training requirements, and medical monitoring. An exclusion zone surrounding the waste feed handling and input area of the Shirco unit required Level C personnel protection from waste feed particles. Access to other sectors within the demonstration area, as agreed upon by FWEI, MDNR, and Shirco health and safety personnel, required Level D personnel protection with coveralls, gloves, boots and coverings, safety glasses, and a hard hat. Discussions with the local fire department ensured that the local authorities who would be responsible for a site emergency response were aware of the test program.

4.2.2 Material Feed

Based on the pretest sampling and analysis, as discussed in Section 4.1, feed material from selected contaminated areas was excavated using a front-end loader and transported to an adjacent flat staging area within the hazardous waste site. The excavated area was located within a steeply sloped, irregular in grade, and overgrown terrain. This precluded a sophisticated large-scale grubbing and excavation operation consistent with the small-scale pretest sampling and analysis that provided the definition of the overall sector as presented in Tables 3, 4, and 5. The staging area was covered with plastic sheeting to eliminate any cross-contamination from the excavated soil to the staging area soil. The excavated soil was mixed using the front-end loader shovel to produce a blended mix and then dumped onto a free-standing screen to remove any debris larger than one inch in diameter before being shoveled into 55-gal drums. Two of the drums were filled with screened soil that had been blended with 3 wt% oil. The drums then were moved into the exclusion zone inside the test area for storage. The material was transferred from the drums to 5-gal pails in 40-lb increments for feeding to the unit. The scale was tared with the pail to zero, so that when the pails were weighed, the weight recorded would be the net weight of the feed. A lid was quickly placed on the pail to minimize any evaporation of organics in the feed.

4.2.3 Operational History

The initiation of the formal demonstration test runs began on November 2, 1987. The program originally was designed to

TABLE 6
PROPOSED TEST MATRIX

Day	Run	Time	Operating temperature		Approximate Waste feed (lbs)	Furnace residence time(min)	Atmosphere	Misc.
			PCC(^{O}F)	SCC(^{O}F)				
1	0 A	0900-1800	1600	2200	40-60	20	Oxidizing	
2	1	0900-1800	1600	2200	40-60	20	Oxidizing	
3	2	0900-1800	1600	2200	40-60	20	Oxidizing	
4	3	0900-1800	1600	2200	40-60	20	Oxidizing	
5	4	0900-1300	1600	1800	35-50	25	Oxidizing	
5	5	1400-1800	1600	2200	40-60	20	Oxidizing	B
6	--------------------DOWNTIME--------------------							
7	--------------------DOWNTIME--------------------							
8	6	0900-1300	1600	1800	50-75	15	Oxidizing	C
8	7	1400-1530	1600	2200	60-90	10	Oxidizing	
8	8	1600-1800	1600	1800	50-75	15	Non-Oxidizing	C
9	9	0900-1300	1200	2200	35-50	25	Nox-Oxidizing	
9	10	1400-1800	1200	1800	35-50	25	Oxidizing	
10	11	0900-1300	1200	2200	40-60	20	Non-Oxidizing	
10	12	1400-1800	1200	1800	40-60	20	Oxidizing	B
11	13	0900-1300	1200	2200	50-75	15	Non-Oxidizing	
11	14	1330-1530	1200	1800	50-75	15	Oxidizing	
11	15	1600-1800	1200	1800	50-75	15	Non-Oxidizing	C
12	16	0900-1300	900	2200	35-50	25	Non-Oxidizing	
12	17	1330-1530	900	1800	40-60	20	Non-Oxidizing	
12	18	1600-1800	900	1800	40-60	20	Non-Oxidizing	C

A - Formal sampling not proposed. System shakedown and checkout to be performed.

B - Secondary combustion chamber to be heated electrically.

C - Feed to be blended with 3-5% fuel oil.

follow the proposed test matrix, as summarized in Table 6 and the daily chronology in Section 4.2.3.1.

Section 4.2.3.2 defines the actual operations and test matrix that was followed during the test program. Differences from the originally proposed program and test matrix are discussed in Section 4.2.3.3.

4.2.3.1 Daily Chronology of Proposed Program

Day 1 of the test program was designed for system shakedown and checkout. The selection of operating parameters during this day was based upon previous experience decontaminating PCB-contaminated soils.

These parameters were also selected for the three replicate runs to be conducted on Days 2, 3, and 4.

Day 5 of the program was to consist of two 4-hour runs with an oxidizing atmosphere in the primary chamber. The residence time in the furnace would be varied to help determine the minimum time required for detoxification. In addition, the secondary combustion chamber temperature would be varied to obtain data regarding optimization of utility requirements. Note that during one of these proposed runs, the secondary chamber was to be heated by electrical heating elements. Results of previous testing conducted with the Shirco system have met EPA-required DREs for PCBs with secondary chamber temperatures of 1800^{0}F.

Days 6 and 7 were set aside for preventative maintenance on the pilot unit and preparation for the following week's testing.

Day 8 of the program was to consist of three runs. One run would employ a non-oxidizing atmosphere in the primary furnace to determine the effect on lead fixation. Temperatures in the secondary chamber and furnace residence time were to be varied again for further optimization of system operating parameters and material throughput. In addition, two of the runs were to be conducted utilizing feed material blended with 3-5% fuel oil. This would provide data regarding maximization of material throughput as well as minimization of utility consumption.

Day 9 of the program was designed to consist of two runs utilizing lower temperature in the primary furnace to determine the minimum operating temperature and the effect on metals present in the feed. The atmosphere in the furnace again would be varied to provide data on metals fixation; the secondary chamber temperature was to be lowered during one run to optimize utility consumption.

Day 10 of the program was to consist of two runs similar to those conducted on Day 9. However, the secondary chamber would be heated electrically to further investigate the potential minimization of utility consumption, and the furnace residence time would be reduced to maximize throughput.

Day 11 of the program was to consist of three runs similar to those of Days 9 and 10; however, furnace residence time would be reduced further. In addition, one of the runs would be conducted utilizing feed blended with fuel oil to determine the effect on material throughput.

Day 12 of the program was to consist of three runs, all of which would be conducted with a non-oxidizing atmosphere and lower temperatures in the primary furnace. The primary objective of these tests was to provide data on potential metals fixation with the Shirco process.

In order to fully evaluate the effect of proposed variations in process operating parameters, composite samples of feed, ash, and scrubber blowdown water were to be taken during each of the runs.

Upon completion of testing, Shirco personnel were to initiate decontamination procedures on the pilot unit and prepare for demobilization 15 days after arrival.

4.2.3.2 Actual Operations

The actual test program schedule of runs deviated from the proposed test matrix outlined in Section 4.2.3.1. The following discussion summarizes the actual operational history of the overall program. Tables 7 and 8 present a summary of the operating conditions and energy input to the unit during the demonstration test runs. The references to run numbers refers to the original proposed test matrix, as discussed and defined in Section 4.2.3.1 and Table 6. The actual test program operated at test conditions for 51 hrs 11 min and processed 1,799 kg (3,967 lbs) of contaminated waste feed.

November 2, 1987. The primary combustion chamber heatup was started at 08:20 hours. When the primary combustion chamber reached 1000^{0}F, the secondary combustion chamber was fired and brought up to 2200^{0}F using maximum propane flow to minimize heatup time. This heatup procedure was followed during all startups. While the sampling and analytical subcontractor was completing the setup of their equipment, the system was maintained at operating temperature. Feed material was introduced to the unit at 15:20 hours at 20 min residence time and a bed depth of 1 1/2-in in the primary combustion chamber. Unit operation continued until 17:13 hours to establish feedrate and stack velocity for the demonstration tests.

TABLE 7
OPERATIONS SUMMARY

Date	Time period	Test run	Primary combustion chamber		Waste feedrate Lb/Hr	Secondary combustion chamber	
			Temperature $^{\circ}F$	Res. time Min.		Temperature $^{\circ}F$	Res. time Sec.
11-02-87	15:20-17:13 (d)	0					
11-03-87	10:20-11:40	-	1600	20	88.89	2200	
	11:40-18:25	1	1600	20	66.53	2200	2.60
11-04-87	07:33-09:45	-	1600	20	69.09	2200	
	09:45-20:13	2	1600	20	73.11	2200	
11-05-87	07:55-08:16	-	1600	20	82.86	2200	
	08:16-18:37	3	1600	20	77.41	2200	
11-06-87	09:55-10:32	-	1600	20	128.57	2200	
	10:32-15:31	1-2(f)	1600	20	70.23	2200	
11-07-87	00:00-24:00 (e)						
11-08-87	00:00-24:00 (e)						
11-09-87	09:34-10:35	10	1200	20	78.68	1800	
	11:26-12:27	14	1200	15	95.41	1800	
	13:45-14:47	5	1400	20	65.81	2200	
11-10-87	09:30-10:30	6	1600	15	110.77 (a)	1800	
	11:20-12:20	8	1600 (b)	15	120.00 (a)	1800	
	13:13-14:14	15	1200 (b)	15	100.33 (a)	1800	
	15:07-16:07	18	900 (b)	20	80.00 (a)	1800	
11-11-87	09:04-10:05	7	1600	10	114.10	2200	
	11:30-12:31	9	1200 (b)	25	62.95	2200	
	13:20-14:20	11	1200 (b)	20	73.85	2200	
	15:10-16:10	13	1200 (b)	15	88.29	2200	
11-12-87	10:27-11:27	16	900 (b)	25	65.00	2200	
	12:35-13:35	17	900 (b)	20	70.00	1800	
11-13-87	10:12-11:12	19	1600 (c)	15	88.29 (a)	1800	

(a) Waste feed blended with approximately 3 wt.% fuel oil.

(b) Test runs conducted under non-oxidizing atmosphere.

(c) Primary combustion chamber bed depth set at 1-in. All other test runs conducted at 1 1/2 inch bed depth.

(d) System shakedown. No formal sampling.

(e) Weekend. Unit shutdown.

(f) Run 1-2 was conducted to makeup for incomplete sampling runs that were to be conducted during Runs 1 and 2.

TABLE 8. POWER USAGE - ACTUAL OPERATIONS

Date	Time period	Hrs.	Primary combustion chamber					Secondary combustion chamber		
	Time intervals		kwhr			kw	kwhr/Lb feed	Propane usage		
			Zone A	Zone B	Cumulative			Lb/Hr	Btu/Hr	Btu/Lb feed
11-03-87	11:40-18:25	6.75	81.5	52.1	133.6	19.79	0.2975	13.75	295895	4458.24
11-04-87	09:45-20:13	10.47	119.3	71.6	190.9	18.24	0.2495	13.45	289463	3914.35
11-05-87	08:16-18:37	10.35	124.3	75.8	200.1	19.33	0.2497	16.38	352501	4560.48
11-06-87	10:32-15:31	4.98	60.5	43.9	103.9	20.85	0.2919	12.56	270165	3846.64
11-09-87	09:34-10:35	1.02	8.6	6.7	15.3	15.05	0.1913	10.73	231570	2992.24
	11:26-12:27	1.02	8.7	6.9	15.6	15.34	0.1608	9.14	197277	2102.14
	13:45-14:47	1.03	9.2	7.5	16.7	16.16	0.2456	17.99	385950	6060.09
11-10-87	09:30-10:30	1.00	12.5	8.7	21.2	21.20	0.1914	9.36	201543	1819.47
	11:20-12:20	1.00	9.0	7.4	16.4	16.40	0.1367	8.97	192975	1608.13
	13:13-14:14	1.02	1.6	3.0	4.6	4.52	0.0451	8.04	173678	1759.91
	15:07-16:07	1.00	0.9	1.3	2.2	2.20	0.0275	10.75	231570	2894.63
11-11-87	09:04-10:05	1.02	12.7	8.5	21.2	20.85	0.1827	16.69	360220	3209.59
	11:30-12:31	1.02	5.4	3.3	8.7	8.56	0.1360	16.69	360220	5817.69
	13:20-14:20	1.00	3.0	2.0	5.0	5.00	0.0678	11.95	257300	3484.09
	15:10-16:10	1.00	7.9	2.6	10.5	10.50	0.1189	11.95	257300	2914.25
11-12-87	10:27-11:27	1.00	5.5	3.6	9.1	9.10	0.1400	17.13	368788	5673.66
	12:35-13:35	1.00	5.8	4.6	10.4	10.40	0.1486	8.77	188678	2695.40
11-13-87	10:12-11:12	1.00	11.8	9.0	20.8	20.80	0.2356	9.96	214408	2428.45

November 3, 1987. The portable unit heatup was started at 05:00 hours to prepare the unit for a test start at 08:00 hours. Feed was introduced to the unit at 07:30 hours to stabilize the unit for testing. Feeding was halted at 08:30 hours and the system was maintained on operating status to allow the sampling and analytical subcontractor the time to complete setup of their equipment. Feed material was again initiated to the unit under an oxidizing atmosphere at 10:20 hours at 20-min residence time and a bed depth of 1 1/2-in in the primary combustion chamber. The primary combustion chamber temperature was set at 1600°F, and the secondary combustion chamber was controlled at 2200°F. Run 1 was started at 11:40 hours with all continuous monitoring and sampling equipment checked out and operating properly. Testing was stopped at 18:25 hours to secure the unit for the night. Because of the shortened operating period during Run 1 the sample trains for semivolatile organics, PCDD/PCDF, and soluble chromium were not run. These remaining sampling runs on Run 1 were rescheduled for November 6 and were conducted during Run 1-2.

November 4, 1987. The portable unit heatup was started at 05:20 hours. Feed was introduced to the unit at 07:33. Run 2, under an oxidizing atmosphere, was not started until 09:45 hours to allow time for the safety meeting and the final setup of sampling equipment. The operating parameters were set at 20-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 1600°F, and a secondary combustion chamber temperature of 2200°F. The secondary combustion chamber automatic temperature control system began to malfunction at 12:45 hours; the operator switched to manual control without affecting the test. As a result of the problem with the secondary combustion chamber control system, the burner tripped off at 15:40 hours. The burner was restarted without affecting the test. Run 2 was completed at 20:13 hours, and unit cooldown began as soon as all of the waste material had been discharged into the ash chute. During Run 2 the Method 5 sampling train for particulate matter malfunctioned and data was not obtained. This sampling run was rescheduled for November 6 and was conducted during Run 1-2.

November 5, 1987. The portable unit heatup was started at 05:35 hours and feed was introduced to the unit at 07:55. Run 3, under an oxidizing atmosphere, was started at 08:16 hours. The operating parameters were retained at the previous settings of 20-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 1600°F, and a secondary combustion chamber temperature of 2200°F. With the exception of the ash discharge screw tripping out momentarily, Run 3 was problem-free and was completed at 18:37 hours. Unit cooldown began as soon as all of the waste material had been discharged into the ash chute.

November 6, 1987. The portable unit heatup was started at 08:30 hours and feed was started to the unit at 09:55. The testing program consisted of the sampling runs that remained from Run 1 and Run 2 and was designated as Run 1-2. The operating parameters were left at the previous settings of 20-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 1600°F, and a secondary combustion chamber temperature of 2200°F. After another delay caused by a leak in the continuous emission monitoring (CEM) system, the test started at 10:32 hours. At 11:20 hours, the venturi recycle flow was lost for no apparent reason. The test equipment was shut down, feeding was resumed, and the test was restarted at 11:40 hours. The test runs were finished at 15:31 hours, and cooldown began as soon as all of the waste material had been discharged into the ash chute.

November 7/8, 1987. The unit was shutdown during the weekend.

November 9, 1987. The portable unit heatup was started at 07:15 hours and feed was introduced to the unit at 08:55 hours. The anticipated test schedule consisted of Runs 10, 14, and 12, all under an oxidizing atmosphere. Run 10, with a 20-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 1200°F, and a secondary combustion chamber temperature of 1800°F, was started at 09:34 and completed at 10:35 hours. After changing the primary combustion chamber material residence time to 15 minutes, Run 14 began at 11:26 and was completed at 12:27 hours. The secondary combustion chamber auxiliary heat source was changed to electrical glowbars for Run 12; however the electrical rods would not hold the temperature in the chamber at the specified 1800°F. After checking and fine-tuning the secondary combustion chamber's heating element power center (HEPC) system, the electrical glowbars again failed to maintain the temperature in the chamber. The propane burner was used to increase the secondary combustion chamber to 2200°F and Run 5, under an oxidizing atmosphere, was carried out to replace Run 12. The primary combustion chamber temperature was increased to 1400°F, and the residence time was verified at 20 minutes. Run 5 began at 13:45 hours and was completed at 14:47 hours. After the testing was finished, the secondary combustion chamber again was changed over to electrical heating and the HEPC system was tuned further in an effort to maintain the desired temperature during operation. Unit cooldown was initiated at 16:00 hours and all equipment was secured for the night.

November 10, 1987. The portable unit heatup was started at 07:55 hours and feed was started to the unit at 08:59 hours. The test schedule consisted of Runs 6, 8, 15, and 18. The feed for these test runs had been blended with 3 wt.% oil prior to the tests. The method of transferring the waste to the incinerator was the same as described above. Run 6, with a 15-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 1600°F, a secondary combustion chamber temperature of 1800°F, and an oxidizing atmosphere was started at 09:30 and was completed at 10:30 hours. After changing to a non-oxidizing atmosphere, Run 8 began at 11:20 hours with the other parameters remaining the same. Run 8 was completed at 12:20 hours. The primary combustion chamber temperature was decreased to 1200°F for the next run while the remaining variables were held constant. Run 15 began at 13:13 hours and was completed at 14:14 hours. For Run 18 the primary combustion chamber temperature was reduced to 900°F, and the residence time was increased to 20 minutes. The run commenced at 15:07 hours and ended at 16:07 hours. After the testing was completed and the waste was totally off the belt, unit cooldown was initiated at 16:32 hours and all equipment was secured for the night.

November 11, 1987. The portable unit heatup was started at 06:15 hours and feed was started to the unit at 08:40 hours. The test schedule consisted of Runs 7, 4, and the rescheduled 12. Run 7 began at 09:04 hours. The test parameters were set at a 10-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 1600°F, a secondary combustion chamber temperature of 2200°F, and an oxidizing atmosphere. The test was completed at 10:05 hours. In an attempt to conduct Runs 4 and 12, the secondary combustion chamber heat source was changed over from propane fuel to electrical power. With the feed material low in organics, the chamber temperature again failed to reach the desired limits. The propane burner was refired and the testing proceeded with Runs 9, 11, and 13. Run 9, with the variables set at 25-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 1200°F, a secondary combustion chamber temperature of 2200°F, and a non-oxidizing atmosphere, began at 11:30 hours and ended at 12:31 hours. The material residence time in the primary combustion chamber was reduced for the next run to 20 minutes; Run 11 commenced at 13:20 hours and was completed at 14:20 hours. For Run 13 the residence time was further reduced to 15 minutes. The run began at 15:10 hours and ended at 16:10 hours. After the testing was finished and the feed was completely off the belt, unit cooldown was started and all equipment was secured for the night.

November 12, 1987. The portable unit heatup was started at 08:45 hours and feed was started to the unit at 09:48 hours. The test schedule consisted of Runs 16 and 17. For Run 16, the parameters were set at a 25-min residence time, a bed depth of 1 1/2-in, a primary combustion chamber temperature of 900°F, a secondary combustion chamber temperature of 2200°F, and a non-oxidizing atmosphere. The run started at 10:27 hours and ended at 11:27 hours. The residence time in the primary combustion chamber was reduced to 20 min, and secondary combustion chamber temperature reduced to 1800°F. Run 17 commenced at 12:35 hours and was completed at 13:35 hours. After the testing was finished and the feed was completely off the belt, the unit was cooled and all support equipment secured for the night.

November 13, 1987. Run 19 was added to the matrix Runs 4 and 12 that were dropped due to the inability to maintain the temperature in the secondary combustion chamber with electrical power and a desire to extend the test operations matrix with the remaining oil-blended soil. The unit heatup was started at 08:25 hours and feed was started to the unit at 09:40 hours. The parameters were set at a 15-min residence time, a bed depth of one inch, a primary combustion chamber temperature of 1600°F, a secondary combustion chamber temperature of 1800°F, and an oxidizing atmosphere. The run started at 10:12 hours and ended at 11:12 hours.

Run 19 was identical to Run 6 except for a reduction in PCC bed depth from 1 1/2 in to one inch to examine the effect on the decontamination of the solid waste feed in the PCC with the more intimate heat effect on the 1-in deep incinerator bed.

With the completion of Run 19, the test matrix for the SITE demonstration program was completed. The Shirco Portable Demonstration Unit was baked out and decontaminated according to the site safety plan. Site equipment was decontaminated and removed from the job site. The remaining contaminated waste, the residual ash, and the scrubber water were stored securely in 55-gal drums, labeled, and set aside on the test site for future disposal. The drums were transported and placed within the MDNR-designated fenced hazardous waste site.

Posttest Activities. Shirco personnel remained on site through November 16, 1987 to complete the decontamination and removal of the Shirco Unit and all support equipment. The Portable Demonstration Unit departed the job site on November 16, 1987.

4.2.3.3 Changes In Operation - Proposed Program Versus Actual Operations

During the second week of testing, the test matrix was modified by Shirco. The test schedule was rearranged into groups of tests with parameters that ensured the most efficient and satisfactory operation of the unit as conditions were varied from test to test.

The scheduled length of time for each run also was shortened to approximately 1 hr from the proposed range of 1.5 to 4 hrs for individual runs. The 1-hr steady-state operation provided sufficient sampling time to ensure representative analytical results for each test run. The unit was operated for approximately 1 hr prior to the sampling period to ensure the steady-state operation of the unit. The shortened test run periods provided the overall program with additional time to effectively coordinate each day's test schedule with the sampling and analytical subcontractor personnel; the health and safety officer and his reviews; and the other state, contractor, and EPA personnel at the site, and still ensure the timely completion of the demonstration tests.

In addition to the changes in the scheduled length of each run, the following changes also were made to individual runs as defined in the proposed test program.

- Runs 4 and 12 were aborted because of an inability to attain an SCC operating temperature of 1800°F when the heat source was changed over from propane fuel to electrical power via the infrared heating rods located in the SCC.
- Run 19 was added to the matrix in place of Runs 4 and 12. Run 19 was identical to Run 6 except for a reduction in the PCC bed depth from 1 1/2 in to 1 in to examine the effect on solid waste decontamination in the PCC with the more intimate heat effect on the 1-in deep incinerator bed.
- Run 10 was operated with a PCC residence time of 20 min instead of the proposed 25 min. Run 5 was operated at a PCC operating temperature of 1400°F instead of the proposed 1600°F. These changes in operation from the proposed bases were not planned and can only be attributable to an inaccurate interpretation of the proposed operating conditions.

4.3 OPERATING LOG DATA

The unit log data as inputted by the Shirco unit operations staff is included in Appendix A, Volume II of this report. The attached Tables 7 and 8 present summaries of the operating conditions and energy input to the unit during the demonstration test runs.

4.3.1 Primary Combustion Chamber Waste Feed Rates

The weight of material fed during all operating periods was recorded in the operating log data included in Appendix A, Volume II. From this log data the average feedrate during a specific test condition was calculated and is presented as the feedrate values shown on Table 7.

The actual test program operated at test conditions for 51 hrs 11 min and processed 1,799 (3,967 lbs) of contaminated waste feed. The total unit operating time including heatup and cooldown periods without waste feed to the unit, and startup, shutdown, and transitional periods between runs at non-test conditions was 74 hrs 21 min. For 66 hrs 48 min of that overall operating period a total of 2,274 kg (5,015 lbs) of contaminated waste feed was processed through the unit.

During each of the emissions sampling test periods, a new pail of material was fed to the unit as emissions sampling was initiated. A series of pails were completely fed to the furnace through the end of the sampling period. The total amount of material fed to the furnace was adjusted for the weight of sample taken. Thus, the waste feed rate is a total amount of waste fed to the unit divided by the time interval for the test run.

4.3.2 Primary Combustion Chamber Residence Time

Recorded on the logsheets included in Appendix A, Volume II and on Table 7 are the material residence times in the primary combustion chamber. The operator adjusted the speed of the furnace conveyor belt for each test condition using electronic control for the motor/gear reducer, a stop watch, and the calibrated scale mounted on the end of the feed end terminal drum shaft. This iterative adjustment is made until the belt speed produces the nominal specified residence time for the test run.

4.3.3 System Operating Temperatures

The average operating temperatures of the primary and secondary combustion chambers during the test periods are presented in Table 7. These averages were derived from the operating log data included in Appendix A, Volume II and the temperature recorder charts.

4.3.4 Power and Fuel Usage

4.3.4.1 Primary Combustion Chamber

A summary of the primary combustion chamber power usage is presented in Table 8. The data is based on the comprehensive log data found in Appendix A, Volume II. Note that this data may not be used as a direct scale-up for a full-scale system.

The portable unit has a much greater surface area per pound of material processed than does a large commercial-scale unit. Thus, the heat loss per pound of feed is proportionately greater. The energy required to overcome the heat loss in the portable unit is a major percentage of the total operating power usage. This compares to a larger-scale system in which the surface heat loss is a small percentage of the operating energy requirement. Full-scale power usage therefore would be proportionately smaller.

4.3.4.2 Secondary Combustion Chamber

A summary of the propane fuel consumption rates for the secondary combustion chamber is presented in Table 8. The data are based on the comprehensive log data included in Appendix A, Volume II.

SECTION 5

SAMPLING AND ANALYSIS PROGRAM

The SITE program for the Shirco Pilot-Scale Infrared Incineration System at the Demode Road Superfund Site was conducted in two phases: under normal/optimum conditions (Phase I) and varied operating conditions (Phase II), as discussed in Section 4. During the first phase measurements were made for three identical test runs conducted over a three-day period. In the second phase runs, parametric factors affecting incinerator performance were evaluated. Tables 9 and 10 present sampling and analytical program summaries for the test runs conducted in each phase, including sampling frequencies, sampling methods, and analytical parameters and methods for each sampling location. The complete Sampling and Analytical report is presented in Appendix B, Volume II. A separate report discussing the results obtained during the continuous monitoring of the PCC offgas for vaporous lead emissions is presented in Appendix F, Volume II.

The demonstration plan for this program, dated October 23, 1987, is included in Appendix C, Volume II. The continuous monitoring of the PCC offgas for vaporous lead emissions is presented in Appendix E, Volume II. These documents provide more detailed discussions and definitions of the overall sampling and analytical procedures and methods discussed in this section.

It should be noted that in the discussions that follow, references to various sampling and analytical protocols are included. These recommended methods for sampling and analyzing samples are coded to the following standards:

o "S" and "A" refer to Arthur D. Little, Inc., "Sampling and Analysis Methods for Hazardous Waste Combustion," EPA 600/8-84-002, PB84-155845, February, 1984.

o "ASTM" refers to American Society for Testing Materials, "Annual Book of ASTM Standards," Philadelphia, Pennsylvania.

o "EPA Method" refers to Code of Federal Regulations 40CFR Part 60, Appendix A, revised as of July 1, 1985

o "M" refers to U.S. EPA, "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, March, 1979.

o "SW" refers to U.S. EPA, "Test Methods for Evaluating Solid Waste-Physical/Chemical Methods," SW-846, Third Edition, November, 1986.

TABLE 9. SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM, PHASE I

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
Stack Gas	Composite over 3- to 6-hour period	EPA Method 5 with 0.1 N NaOH	Particulate Matter	EPA Method 5
			HCl	Ion Chromatography
			Volumetric flowrate	EPA Methods 1-4
			Moisture	EPA Method 4
			Metals (particulate on filter)	SW 6010,7060,7041,7421 7740,7470/7471
	Composite over 3- to 6-hour period	SASS with XAD-2 (SW0020)	PCB	EPA 680
	Composite over 3- to 6-hour period	SASS with XAD-2 (SW0020)	PCDD/PCDF	SW 8280
			Semivolatile Priority Pollutants (plus 10 higher peaks)	SW 8270
	Composite over 4 hour period	Modified Method 5 (No filter/0.1 N NaOH)	Soluble Chromium	M218.4
		Gas bag (Grab)	CO_2, O_2	EPA Method 3
	6 pairs of samples over 2 hour period (one aqueous condensate)	VOST (SW0030)	Volatile Priority Pollutants (plus 10 highest peaks)	SW 8240
	Continuous	Continuous emission monitors	O_2	Paramagnetic
			CO_2	NDIR
			CO	NDIR
			THC	FID
			NO_x	Chemiluminescence

(continued)

TABLE 9 (continued)

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
Primary Furnace Offgas	Composite over 3- to 6-hour period	EPA Method 5 with 0.1 N NaOH	Particulate Matter HCl Volumetric flowrate Moisture Metals (particulate on filter)	EPA Method 5 Ion Chromatography EPA Methods 1-4 EPA Method 4 SW 6010,7060,7041,7421 7740,7470/7471
	Composite over 3- to 6-hour period	SASS with XAD-2 (SW0020)	PCB	EPA 680
	Composite over 3- to 6-hour period	SASS with XAD-2 (SW0020)	PCDD/PCDF Semivolatile Priority Pollutants (plus 10 higher peaks)	SW 8280 SW 8270
	Composite over 4 hour period	Modified Method 5 (No filter/0.1 N NaOH)	Soluble Chromium	M218.4
		Gas bag (Grab)	CO_2, O_2	EPA Method 3
	6 pairs of samples over 2 hour period (one aqueous condensate)	VOST (SW0030)	Volatile Priority Pollutants (plus 10 highest peaks)	SW 8240
	Continuous	Continuous emission monitors	O_2 CO_2 CO THC NO_x Lead	Paramagnetic NDIR NDIR FID Chemiluminescence EPRI/DOE Special

(continued)

TABLE 9 (continued)

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
Solid Waste Feed	Grab sample every 30 minutes and composite	S007	Chlorine	A003
			PCDD/PCDF	SW8280
			PCB	EPA 680
			Metals	SW 6010,7060,7041, 7421,7740,7470/7471
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114
			EP Toxicity	C004,SW1310
			Volatile Priority Pollutants (plus 10 highest peaks)	SW8240
			Semivolatile Priority Pollutants (plus 10 highest peaks)	SW8270
			Moisture, Ash	A001
			Ultimate	A003
			Higher Heating Valve	A006
			Density	GRAV/VOL
Scrubber Solids	Sample at end of test period and composite	S002	PCB	EPA 680
			PCDD/PCDF	SW8280
			Chlorine	A003
			Metals	SW 6010,7060,7041 7421,7740,7470/7471
			EP Toxicity	C004, SW1310
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114
			Volatile Priority Pollutants (plus 10 highest peaks)	SW 8240

(continued)

TABLE 9 (continued)

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
			Semivolatile Priority Pollutants (plus 10 highest peaks)	SW 8270
			Ash	A001
			Ultimate	A003
			Density	GRAV/VOL
Scrubber Makeup Water	Sample at end of test period and composite	S004	PCB	EPA 680
			PCDD/PCDF	EPA 8280
			pH	M150.1
			Chloride	Ion Chromatography
			Metals	SW 6010,7060,7041, 7421,7740,7470/7471
			Volatile Priority Pollutants (plus 10 highest peaks)	SW 8240
			Semivolatile Priority Pollutants (plus 10 highest peaks)	SW 8270
			Total Organic Carbon	M415.1
			Total Suspended Solids	M160.1
			Total Dissolved Solids	M160.2
Ambient Air	Continuous during unit operation; One upwind and one downwind	General Metal Works Model PS-1 Air Sampler w/ Polyurethane Foam (PUF) Plugs and Florisil Sorbent	PCB	EPA 680
		General Metal Works Model 2000H High Volume Sampler w/ glass fiber filters	Metals	SW 6010,7060,7041 7421,7740,7470/7471

(continued)

TABLE 9 (continued)

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
Furnace Ash	Sample composite at end of test period	S007	PCB	EPA 680
			PCDD/PCDF	SW 8280
			Metals	SW 6010,7060,7041,7421 7740,7470/7471
			EP Toxicity	C004, SW1310
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114
			Volatile Priority Pollutants (plus 10 highest peaks)	SW 8240
			Semivolatile Priority Pollutants (plus 10 highest peaks)	SW 8270
			Moisture, Ash	A001
			Chlorine	A003
			Density	GRAV/VOL
Scrubber Water	Sample at end of test period	S002	PCB	EPA 680
			PCDD/PCDF	EPA 8280
			pH	M150.1
			Chlorine	Ion Chromatography
			Metals	SW 6010,7060,7041, 7421,7740,7470/7471
			EP Toxicity	C004, SW1310
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114

(continued)

TABLE 9 (continued)

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
			Volatile Priority Pollutants (plus 10 highest peaks)	SW 8240
			Semivolatile Priority Pollutants (plus 10 highest peaks)	SW 8270
			Total Organic Carbon	M415.1
			Total Suspended Solids	M160.1
			Total Dissolved Solids	M160.2

TABLE 10. SUMMARY OF SAMPLING AND ANALYTICAL PROGRAM, PHASE II

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
Stack Gas and Primary Furnace Offgas	Composite over 3- to 6-hour period	EPA Method 5	Particulate Matter	EPA Method 5
			Volumetric flowrate	EPA Methods 1-4
			Moisture	EPA Method 4
	Continuous	Continuous emission monitors	O_2	Paramagnetic
			CO_2	NDIR
			CO	NDIR
			THC	FID
			NO_x	Chemiluminescence
Solid Waste Feed	Grab sample every 30 minutes and composite	S007	PCDD/PCDF	SW8280
			PCB	EPA 680
			Metals	SW 6010,7060,7041, 7421,7740,7470/7471
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114
			EP Toxicity	C004,SW1310
			Moisture, Ash	A001
			Ultimate	A003
			Density	GRAV/VOL
Scrubber Solids	Grab sample once per hour and composite	S002	PCB	EPA 680
			PCDD/PCDF	SW8280
			Metals	SW 6010,7060,7041 7421,7740,7470/7471
			EP Toxicity	C004, SW1310
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114
			Ash	A001
			Ultimate	A003
			Density	GRAV/VOL

(continued)

TABLE 10 (continued)

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
Ambient Air	Continuous during unit operation; one upwind and one downwind	General Metal Works Model PS-1 Air Sampler w/ Polyurethane Foam (PUF) Plugs and Florisil Sorbent	PCB	EPA 680
		General Metal Works Model 2000H High Volume Sampler w/ glass fiber filters	Metals	SW 6010,7060,7041, 7421,7740,7470/7471
Furnace Ash	Sample at end of test period and composite	S007	PCB	EPA 680
			PCDD/PCDF	SW 8280
			Metals	SW 6010,7060,7041,7421, 7740,7470/7471
			EP Toxicity	C004, SW1310
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114
			Moisture, Ash	A001
			Chlorine	A003
			Density	GRAV/VOL

(continued)

TABLE 10. (continued)

Source	Sample collection frequency	Sampling method	Analysis parameters	Analysis method
Scrubber Water	Sample at end of test period and composite	S002	PCB	EPA 680
			PCDD/PCDF	EPA 8280
			pH	M150.1
			Metals	SW 6010,7060,7041, 7421,7740,7470/7471
			EP Toxicity	C004, SW1310
			TCLP (Proposed)	Fed. Reg. Vol. 51, No. 114
			Total Organic Carbon	M415.1
			Total Suspended Solids	M160.1
			Total Dissolved Solids	M160.2

- "SASS" refers to U.S. EPA, "Modified Method 5 Train and Source Assessment Sampling System Operator's Manual," EPA-600/8-85-003, February, 1985.

- "VOST" refers to U.S. EPA, "Protocol for the Collection and Analysis of Volatile POHCs Using VOST," EPA-600/8-84-007, March, 1984.

- "EPA" refers to U.S. EPA, "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," EPA-600/4-82-057.

5.1 SAMPLING PROCEDURES

5.1.1 Sampling Locations

The streams that were sampled, at locations depicted in Figures 5 and 6, are:

1. Stack Gases
2. Primary Furnace Offgas
3. Feed
4. Furnace Ash
5. Scrubber Water
6. Scrubber Solids
7. Scrubber Makeup Water
8. Ambient Air, upwind and downwind

5.1.1.1 Stack Gases

Secondary combustion chamber gases were drawn through the scrubber unit by an induced draft fan and exhausted through a 4.0-in ID stack. The stack extended through the roof of the trailer to an elevation of 23.6 feet above grade (10 feet above the trailer roof). The stack was equipped with sampling ports accessible from the trailer roof. Because of the size of the exhaust stack, the duct was not traversed. All samples were collected at a single point in the center of the pipe.

About 3 feet above the roof of the trailer was a 3-in flanged port and a 1-in sample tap. Approximately 3 feet above these ports was another 3-in flanged port. The two 3-in ports above the trailer roof were used to collect source assessment sampling system (SASS), Method 5, and Modified Method 5 samples. Prior to the point at which the exhaust stack passes through the trailer roof was a 2-in port accessed through a bulkhead in the trailer. Volatile organic sampling train (VOST) samples were collected at this location.

The 1-in port above the roof had been projected as the CEM sampling tap. However, due to the potential for in-leakage through the 3-in port at the same location during sampling

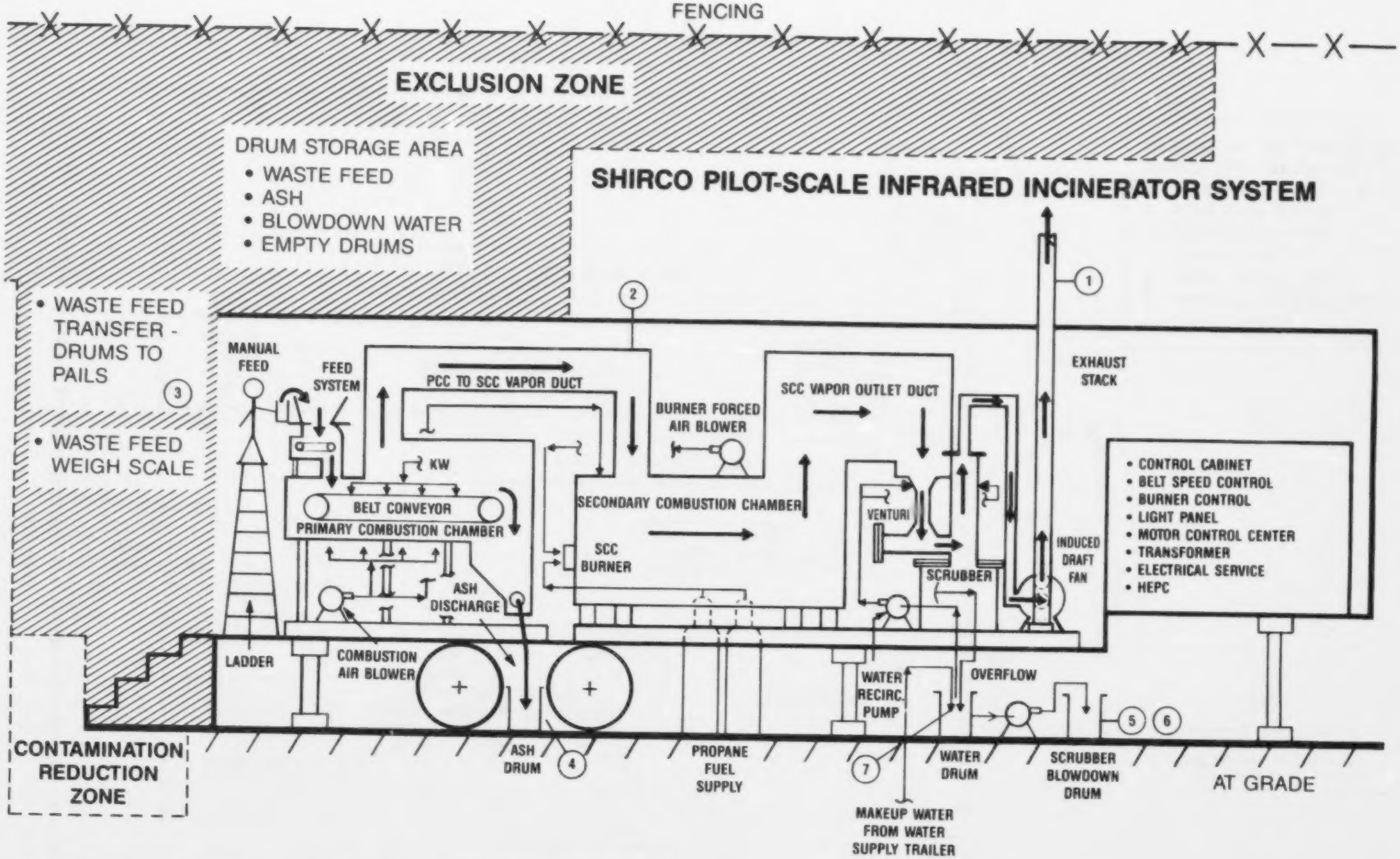

Figure 5. Sampling locations - system process flow.

1 STACK GASES
2 PRIMARY FURNACE OFFGAS
3 SOLID WASTE FEED
4 FURNACE ASH
5 SCRUBBER WATER
6 SCRUBBER SOLIDS
7 SCRUBBER MAKEUP WATER

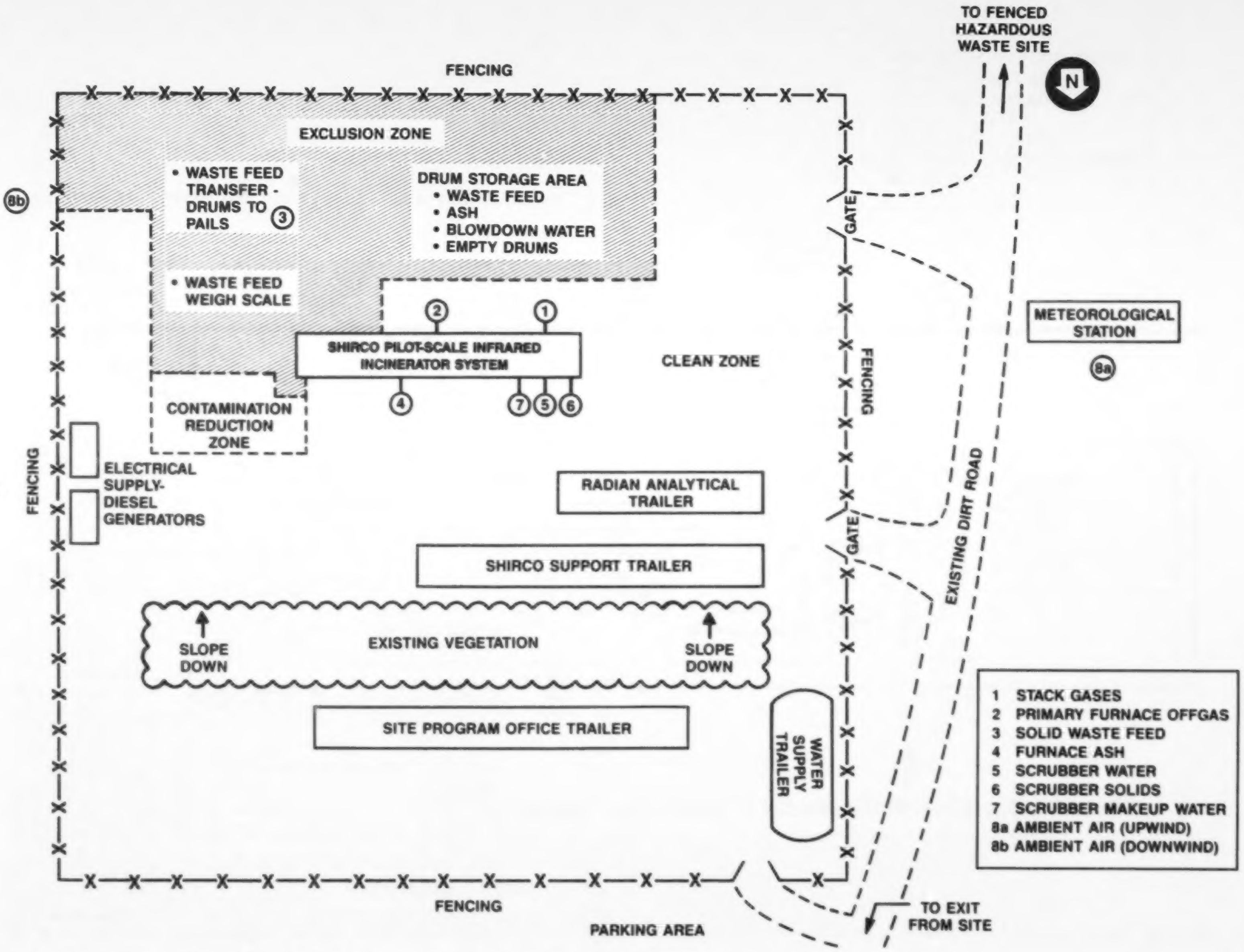

Figure 6. Sampling locations - overall test site.

activities, a sampling tap was installed in the exhaust pipe upstream of the VOST sampling port.

In addition to the above ports, a 2-in tap was installed to accommodate a fixed pitot tube and thermocouple in the exhaust stack to continuously monitor stack flue gas velocity.

Because of the small exhaust duct size, following conventional sampling protocol using a nozzle, pitot, and thermocouple at the sampling point in the duct would overly obstruct flow and potentially bias data. With this tap, flue gas velocity was monitored upstream of the sampling locations in an unobstructed flow region. These data were used to determine isokinetic sampling rates.

5.1.1.2 Primary Furnace Offgas

The offgas from the primary furnace passed through a 2x2-ft duct into the secondary combustion chamber. There were two 4-in 150-lb flanged ports available for sampling access located on either side of the duct. An additional 1-inch port also was available for collection of sampling gas for the continuous monitors. Sampling access was via 1x2-ft bulkheads on either side of the trailer and in line with the ports.

5.1.1.3 Feed

Grab samples were collected by Shirco personnel every 30 minutes during the tests from the incinerator feed pail using a scoop. Two liters of sample were collected during each of the runs. Samples for analysis were composited in 1-liter amber glass jars with teflon-lined caps.

5.1.1.4 Furnace Ash

Ash samples were collected from the ash collection drum at the end of each test period. The samples were collected and composited in 1-liter amber glass jars with teflon-lined lids.

5.1.1.5 Scrubber Water

The scrubber water was recirculated through a 50-gal drum outside of the incinerator trailer. Samples of the scrubber water were taken at the end of each test period from the drum using a dipper. Six liters of scrubber water were collected in amber glass jars with teflon-lined lids, along with three 40-mL volatile organic analysis (VOA) vials.

5.1.1.6 Scrubber Solids

Particulate matter and salts were removed from the exhaust gas by a venturi scrubber. These solids settled out of the scrubber water and collected at the bottom of the 50-gal recirculation drum. Scrubber solids were to be collected at the end of each test period using a dipper. Approximately 2,500 grams of sample were required to achieve all analytical requirements; during the test period, insufficient solids were collected to accommodate analytical requirements, and the analysis of scrubber solids was eliminated. During each test, several scrubber water samples were collected and analyzed for total suspended solids to evaluate the solids loading of the scrubber water.

5.1.1.7 Scrubber Makeup Water

Samples of the scrubber makeup water were collected from a tap in the line running from the holding tank to the scrubber intake port at the end of each test period. Six liters of scrubber make-up water were collected in amber glass jars with teflon-lined lids, along with three 40-mL VOA vials.

5.1.1.8 Ambient Air

PCB concentration in the ambient air and metals concentrations in the ambient air particulate matter were measured upwind and downwind of the incineration area during the demonstration tests. Samples were collected continuously during the operation of the unit.

5.1.2 Process Data

Shirco operating personnel recorded process data during the test periods at hourly intervals. Selected process data is included in Section 4. Actual operating log data is included in Appendix A, Volume II.

5.1.3 Stack Gas and Primary Furnace Offgas Sampling Procedures

5.1.3.1 EPA Method 5

The stack gas and primary furnace offgas were sampled for measurement of particulate matter, HCl, volumetric flowrate, moisture, and metals using an EPA Method 5 sampling train. The method was modified by including 0.1 N NaOH in the impingers to collect HCl.

Based on the EPA Method 5 technique, a sample of particulate-laden flue gas was withdrawn isokinetically using a gooseneck nozzle and heat-traced, glass-lined probe. The particulate matter was collected on a glass fiber filter maintained at a temperature in the range of $248^{0} \pm 25^{0}$ F. The particulate mass was determined gravimetrically from the residues collected on the filter and in the probe and associated glassware prior to the filter. After the filter, the flue gas entered a chilled impinger train where HCl was collected in the first two Greenburg-Smith impingers, which contained 200 mL of 0.1 N NaOH. A third dry impinger was employed to collect condensate or mist carryover from the previous impingers. The third impinger was a modified Greenburg-Smith type. The fourth impinger contained a known weight of silica gel desiccant to collect remaining moisture. A pump and dry gas meter were used to control and monitor the gas flowrate.

During collection of EPA Method 5 samples, S-type pitot measurements were taken in the flue gas duct to determine the isokinetic sampling rate. The pitot differential pressure measurements, along with the flue gas composition (CO_2, O_2, N_2, H_2O), also were used to determine the volumetric flue gas flowrate by correlation to the cross-sectional area of the duct at the sampling location. Grab samples of the stack gas were collected to determine the concentrations of CO_2 and O_2 directly and N_2 by difference, in accordance with EPA Method 3 protocol. The moisture content of the sample gas was measured during the runs following EPA Method 4 protocol.

At the end of the sampling period, the nozzle, probe liner, and glassware preceding the filter housing were rinsed with acetone and deionized water to remove particulate matter. The resulting wash was evaporated and the mass of particulate residue was determined gravimetrically. The glass fiber filter was removed from the filter holder, desiccated for 24 hours, and weighed to determine the mass of particulate on the filter. The total mass of particulate present on the filter and in the probe wash then was divided by the total volume of gas sampled to determine the particulate loading.

The impingers used during particulate sampling were weighed before and after sampling to determine the moisture content of the flue gas. The HCl concentration of the flue gas was determined by analyzing two sodium hydroxide impingers for chloride. Since the impinger solutions were caustic, CO_2 also was removed. To account for the CO_2 removal, the 0.1 N NaOH impinger solutions also were analyzed for carbonate. The metered gas sample volume was adjusted using the carbonate analytical values.

The particulate matter collected on the glass fiber filter was analyzed for metals. The measured metals concentration along with the particulate loading and flue gas flowrate were used to determine the emission rates of those metals.

5.1.3.2 Source Assessment Sampling System (SASS)

SASS trains were used to collect samples of the stack gas and primary furnace offgas for the determination of PCBs, SV-PP+10, and PCDDs/PCDFs. Samples were collected in separate SASS trains for PCBs, semivolatile priority pollutants (identifying the ten highest other peaks), and PCDDs/PCDFs.

The sampling system consisted of a heated probe, a heated filter, a condenser, a sorbent module containing an organic adsorption resin (XAD-2) used to efficiently collect vapor phase organics, and a pumping and metering unit. Because of the low particulate loading in the gas stream, the three cyclones of the SASS were removed from the train for sampling. The probe was a stainless steel sheath, which contained a heat-traced stainless steel sample liner. A gooseneck nozzle of proper size to allow near-isokinetic sample collection was attached to the probe. The probe was fixed to the heated enclosure, which housed a high-efficiency glass fiber filter. The enclosure was maintained at a temperature of 400°F.

From the heated filter, the sample gas entered a water-cooled condenser followed by the XAD-2 sorbent module. A condensate trap followed the sorbent module, which collected the aqueous condensate.

After the condensate trap were three dry impingers to collect any mist carry-over from the condensate trap and a final impinger containing a desiccant to dry the sample gas prior to metering. The sample gas was drawn by two double diaphragm pumps, and the sample gas volume was measured using a dry gas meter.

The design of the SASS train precluded traversing of the stack. Sample collection was performed at a point of average gas velocity that was selected based on previously determined velocity traverse data. The SASS probe included a fixed pitot tube and thermocouple in the exhaust stack to continuously monitor stack gas velocity.

5.1.3.3 Soluble Chromium

Soluble chromium (hexavalent chromium) sampling of the stack gas and primary furnace offgas was conducted according to the procedures (with modifications) currently being used by the EPA's Emission Measurement Branch (EMB) of the Office of Air Quality, Planning, and Standards (OAQPS), Research Triangle Park, NC for sampling hexavalent chromium emissions from municipal waste incinerators. This procedure involves the use of an EPA Method 5 sampling train with the following modifications:

- 0.1 N NaOH impingers in place of water.
- No filter.
- A glass nozzle in place of stainless steel.
- 0.1 N NaOH rinse to recover the sample.

- Minimal 0.1 N NaOH in the sample recovery process.

The nozzle, probe liner, and pre-impinger glassware rinse were added to the impinger catches and the sample analyzed by atomic absorption spectroscopy. The soluble chromium sampling train was run approximately 4 hours at a point of average flue gas velocity to achieve adequate analytical sensitivity.

5.1.3.4 Volatile Organic Sampling Train (VOST)

The stack gas and primary furnace offgas were sampled for volatile organic compounds and priority pollutants (plus the 10 highest peaks) using the VOST. The VOST was designed to collect volatile organics with boiling points less than 100°C using a pair of absorbent resin traps in series.

Volatile organics were removed from the gas in sorbent resin traps containing Tenax and Tenax-charcoal maintained at 68°F. The first resin trap contained Tenax, and the second trap contained Tenax followed by petroleum-based charcoal. After sampling, the resin traps were sealed and returned to the laboratory for analysis. A 20-L sample of gaseous effluent was collected at a flowrate of 1.0 L/min using a glass-lined probe. A dry gas meter was used to measure the volume of gas passed through the pair of traps.

During the test, the VOST run consisted of collecting six pairs of traps, with each pair of traps exposed to sample gas for 20 minutes at the 1.0 L/min flowrate. After daily sampling, two 40-mL VOA vials were used to collect the aqueous condensate collected in the condenser. Three analyses were performed on the six resin trap pairs and on one of the aqueous condensate vials. The samples were collected at a fixed point of average gas velocity in the duct. Isokinetic sampling was not required since the volatile POHCs were in the gas phase.

5.1.3.5 Molecular Weight

Stack gas and primary furnace offgas were collected at a single point in the stack in tedlar gas bags for determination of O_2 and CO_2 concentrations. The samples were extracted through a stainless steel probe and passed through a silica gel impinger to dry the gas before collection in the gas bag. Analysis was conducted by EPA Method 3.

5.1.3.6 Continuous Emission Monitors (CEMs)

CEMs were used during the demonstration test to continuously monitor the concentrations of CO, CO_2, O_2, NO_x, and THC in the stack gas or primary furnace offgas using one set of instruments, which were switched between the two sources every

30 minutes. A stainless steel probe was inserted at the stack gas and primary furnace offgas sampling locations. Gases were withdrawn and transported via separate heat-traced (at 300°C) Teflon@ sample lines to the instrumentation area. There the stack gas and primary furnace offgas sample lines were fed into a three-way valve. The selected stream was conditioned prior to analysis to remove both particulate matter and water.

Gases first entered an impinger train having a series of short-stemmed impingers (as condensers) immersed in an ice bath. After the impinger train, particulate matter was removed by a glass fiber filter. After filtration, the gases were further dried using a Perma-Pure dryer, which utilizes a water vapor permeable membrane. The gases were drawn by a Teflon^R coated diaphragm pump located between the filter and the Perma-Pure dryer. Gases for the five instruments (discussed below) were drawn from a manifold downstream of the pump.

A Bendix Model 85-105CA analyzer was used to measure CO concentration in the gases. This instrument is a nondispersive infrared (NDIR) analyzer, which measures the concentration of CO by infrared absorption at a characteristic wavelength. To measure the CO_2 concentration in the gases, an MSA Model 303 NDIR analyzer was used. This instrument measures the concentration of CO_2 by infrared absorption at a characteristic wavelength.

A Taylor Model 540A oxygen analyzer was used to determine the O_2 concentration of the gases. The Taylor 540A measures oxygen concentrations on the basis of the strong paramagnetic properties of O_2 compared to other compounds present in combustion gases. In the presence of a strong magnetic field, O_2 molecules become temporary magnets. The Taylor 540A determines the sample gas O_2 concentration by detecting the displacement torque of the sample test body in the presence of a magnetic field.

A TECO Model 10 analyzer was used to measure the concentration of NO_x present in the gases. This instrument determines NO_x concentrations by converting all nitrogen oxides in the sample gas to nitric oxide and then reacting the nitric oxide with ozone. The reaction produces a chemiluminescence proportional to the NO_x concentration in the sample gas. The chemiluminescence is measured using a high-sensitivity photomultiplier.

A Beckman Model 400A was used to continuously measure the concentration of hydrocarbons present in the gases. The analyzer utilizes a hydrogen flame ionization detector. The sensor is a burner in which a regulated flow of sample gas passes through a flame sustained by regulated flows of a fuel gas and air. Within the flame, the hydrocarbon components of the sample stream undergo a complex ionization that produces electrons and positive ions. Polarized electrodes collect these ions, causing current to flow through an electronic measuring circuit. The ionization current is proportional to the rate at which carbon atoms enter the burner and is, therefore, a measure of the concentration of hydrocarbons in the original sample.

5.1.4 Primary Furnace Offgas Vaporous Lead Emission Monitoring - Sampling System

The Test Plan for the experimental primary furnace offgas sampling system is presented in Appendix E, Volume II. It was modified in the field to accomodate the port configuration on the PCC offgas duct. The sampling system was intended to continuously sample the primary furnace offgas as feed to an experimental continuous vapor phase monitor for selected metals, including lead. The sampling system was not defined by an approved EPA method or QAPP review but was incorporated into the overall program to study the system's ability to provide real time sampling of the vapor stream and subsequent analysis of the lead emissions as process conditions were varied at the PCC. The sampling system is a probe consisting of a Type-316 stainless steel tube covered by a glass "sock" inserted into the sample port. The remainder of the sample line was heat-traced Type-316 stainless steel tubing. The stainless steel ran from the sample port out the side of the incinerator trailer, down to a heated sample pump, and then to the instrument, a total run of about 20 feet. The sample line had distinct temperature zones. The first zone extended from the primary furnace sample port to approximately three feet before the vacuum pump. In this zone, the temperature was always in excess of 750°F. Since the pump was rated at 700°F, the gas temperature was maintained at approximately 700°F through the pump. Finally, the sample gas stream was cooled to approximately 480°F for introduction into the burner head.

The primary furnace offgas was at a negative pressure relative to atmosphere. Therefore, a heated vacuum pump was used to deliver the primary furnace offgas to the fuel inlet. (Laboratory tests had earlier indicated that sample introduction to the oxidant side negatively influenced nebulization rate and produced back-pressures in the sample line.) To prevent changes in the flame characteristics from one type of sample to another, all gases (calibration, blend, sample) were introduced into the fuel side feed of the burner head.

Experiments were performed using the GBC-900 atomic adsorption spectrophotometer. A single-element hollow cathode lamp was used for the determination of lead. The GBC was equipped with an impact bead nebulizer and pre-mix air-acetylene burner head. Data was recorded in two formats: numerical output from the integration mode of the GBC-900, and direct output to a Soltex 1242 stripchart recorder. Industrial grade air and acetylene were used to establish the flame. The gas blend originally chosen had a certified composition of 5.0 percent CO_2, 8.0 percent O_2, and 87 percent N_2.

5.1.5 Solid and Liquid Sampling Procedures

Sampling procedures that were used to collect samples from solid and liquid streams are described in this section.

5.1.5.1 Solid and Liquid Sample Container Preparation

Sample containers for the solid and liquid samples were organic-free and sealed prior to receipt in the field. All sample bottles used for solid and liquid samples were amber glass with Teflon^{R} cap liners.

Each sample bottle that was used to store samples for organic analysis was pre-cleaned using the following procedure: cleaned initially with a phosphate-free soap; rinsed three times with tap water; rinsed three times with deionized water; rinsed with nitric acid; rinsed three times with deionized water; rinsed with methylene chloride; baked in an oven for 6 hours at 200°C; and allowed to cool and then capped.

5.1.5.2 Solid Sampling Procedures

Samples of the feed, furnace ash, and scrubber solids were collected using a scoop, trier, or dipper, as specified in Methods S007, S006, and S002. Furnace ash and scrubber solids were collected at the end of each test period. Approximately 2,500 g of sample were necessary for analysis.

A uniform amount of solid waste feed was collected every 30 minutes and placed in a sealed container. For each test, at least 2,500 g was collected, and the total sample was used for subsequent analysis.

5.1.5.3 Liquid Sampling Procedures

Scrubber water and scrubber makeup water samples were collected respectively using the dipper and tap sampling procedure specified in Method S002 and S004. Liquid samples were collected at the end of the test period. The sample tap was flushed each time (allowed to flow briefly) before scrubber makeup water was collected. This ensured that any stagnant accumulation of solids, or other contaminants that were present in the tap, did not affect the sample integrity or its representation of the liquid process stream. Scrubber water was collected directly from the accumulation drum. More than 6 liters of sample were collected.

At each sample collection, three 40-mL VOA (void of air) sample vials were collected for analysis of volatile priority pollutants plus the ten highest peaks (V-PP+10). The vials were filled completely and no air bubbles allowed to remain in the bottles. The VOA samples were composited at the time of analysis by syringe accumulation from the selected subsamples to provide one sample per test period for analysis.

5.1.6 Ambient Air Sampling Procedures

Ambient air both upwind and downwind of the test site was sampled and analyzed for PCBs and ambient air particulate matter was analyzed for metals during the operation of the Shirco unit. The upwind and downwind samplers were located using on-site, continuous meteorological data, i.e., wind direction. The wind direction was checked at least once per hour, and, since samplers should not be moved after sampling has begun, if the average wind direction deviated by more than 90^0, ambient sampling was terminated for that period.

5.1.6.1 PCBs

Ambient concentrations of PCBs were determined upwind and downwind of the site during the test programs using the polyurethane foam (PUF) technique. Monitoring was performed using General Metals Works Inc. (GMW) Model PS-1 air samplers.

5.1.6.2 Metals

Ambient concentrations of metals upwind and downwind of the site were measured using a General Metal Works Model 2000H High Volume Sampler. Particulate matter was collected on 8x10-in glass fiber filters and analyzed for metals. The technique also determined the ambient concentration of particulate matter. The downwind location was varied each day based on the meteorological measurement indication of the wind direction.

5.1.6.3 Meteorological Measurements

During the siting of the ambient air sampling stations, a location for the meteorological monitoring station also was chosen. The meteorological data was captured using a battery operated portable meteorological station (Meteorological Research Instruments Model 1072) positioned at the 10-ft level. Wind direction and wind speed were recorded on a stripchart recorder. Temperature measured by the meteorological station was recorded on a stripchart recorder;

all other temperature measurements were recorded by hand and entered on the data sheet.

5.1.7 Sampling Equipment Calibration Procedures

An important function in maintaining data quality is the checkout and calibration of the source sampling equipment. Using referenced procedures, the equipment was calibrated prior to field sampling at the Radian laboratories, and the results have been properly documented and retained.

5.1.7.1 S-Type Pitot Tube

The EPA has specified guidelines, as presented in Section 3.1.1 of EPA Document 600/4-77-027b ("Quality Assurance Handbook for Air Pollution Measurement Systems," August, 1977) concerning the construction and geometry of an acceptable S-type pitot tube. Only S-type pitot tubes meeting the required EPA specifications were used during this project. Prior to the field sampling, the pitot tubes were inspected and documented as meeting EPA specifications.

5.1.7.2 Sampling Nozzle

EPA Method 5 prescribes the use of stainless steel gooseneck nozzles for isokinetic particulate sampling. All nozzles used for the EPA Method 5 particulate sampling, Modified Method 5 sampling and SASS sampling were thoroughly cleaned, visually inspected, and calibrated according to the procedure outlined in Section 3.4.2 of EPA Document 600/4-77-027b.

5.1.7.3 Differential Pressure Gauge

Magnehelic^R gauges were used during this project to measure differential and static pressures. In Section 3.1.2 of EPA Document 600/4-77-027b, the technique used to calibrate the Magnehelic^R is described. The Magnehelic^R gauges were calibrated prior to field sampling and checked at a single representative value following the field sampling.

5.1.7.4 Temperature Measuring Device

During source sampling, accurate temperature measurements are required. Thermocouple temperature sensors were calibrated using the procedure described in Section 3.4.2 of EPA Document 600/4-77-027b. All sensors were calibrated prior to field sampling.

5.1.7.5 Dry Gas Meter

Dry gas meters (DGMs) were used in the SASS, Modified Method 5, Method 5, and VOST trains to monitor the sampling rate and to measure the sample volume. All DGMs were calibrated (documented correction factor at standard conditions) just prior to the departure of the equipment to the field. A posttest calibration check also was performed. The pretest and posttest calibrations agreed to within 5 percent.

The DGMs used in the SASS, Modified Method 5, and Method 5 trains were calibrated using the calibration system procedure outline in Section 3.3.2 of EPA Document 600/4-77-027b.

Rockwell DGMs were used during the SASS, Modified Method 5 and Method 5 tests. A Singer Model DTM-115 low-flow DGM was used during the VOST testing.

5.1.7.6 Analytical Balance

During the field measurement program, the analytical balances were calibrated over the expected range of use with standard weights (NBS Class S) on a daily basis. Measured values were required to agree within ±0.1 mg.

5.1.7.7 CEMs

Calibrations of all continuous monitors were accomplished by introducing standard gases at the front end of the CEM sampling probe prior to and after daily sampling. This allowed for the assessment of any impact caused by the sample gas conditioning system, including the heat-traced sample line, on the pollutants being monitored. All instruments underwent multipoint linearity checks (two points plus zero), bracketing the predicted sample values. These checks were performed at the beginning and end of the sampling period.

An analytical blank and a single-point response factor (RF) standard was analyzed daily prior to testing for all continuous monitors. A single-point drift check also was performed by analyzing the same standard used for the single-point RF determination at the end of each day of testing.

5.1.7.8 PUF Sampler Calibration

Calibration of the General Metal Works (GMW) PS-1 sampler is performed using a GMW Model 40 orifice calibration unit (OCU). This unit initially is calibrated by the manufacturer and is accepted only if a linear regressions analysis of the data yields a correlation coefficient of at least 0.9998. The GMW PS-1 samplers will be calibrated prior to inception of the project. The sampler will be recalibrated at the end of this project. The calibration information is recorded on a standardized data form.

5.1.7.9 Hi-Volume Sampler Calibration

Multipoint flowrate calibrations of the Hi-Vol sampler flow rate recorders were performed using the procedures outlined in 40 CFR, Part 50.11, Appendix B, July 1, 1975. A calibrated orifice and a series of five resistance plates were used to calibrate the flow recorder response.

5.1.7.10 Meteorological Equipment Calibration

The following calibration procedures for the meteorological sensors were performed once in the field prior to sampling:

- Wind Direction--The wind sensor was set at north, south, east, and west. The recorder was checked at each setting for correct response. The setting for north was determined using a compass. A correction for the site declination was made during data analysis.

- Wind Speed--The chart speed was checked for consistent movement.

- Temperature--The thermocouples were calibrated by comparison of three separate measurements against an ASTM reference thermocouple at different times of day. The measuring thermocouple was positioned in close proximity to the temperature sensor of the meteorological station. The temperature readout of the stripchart recorder on the meteorological station then was compared to the reference thermocouple.

All calibration data and test data from meteorological sensors were recorded on meteorological instrumentation calibration forms.

5.1.8 Sample Custody

Sample custody procedures for this program were based on EPA-recommended procedures. Since samples were analyzed on site, as well as at the laboratory facilities, the custody procedures used emphasized careful documentation of monitoring, sample collection, and field analytical data generation, and the use of chain-of-custody records for samples being transported.

The field sampling leader was responsible for ensuring that proper custody and documentation procedures were followed for the field sampling and field analytical efforts. He was assisted in this effort by the sampling personnel involved in sample recovery.

All sampling data, including sampling times, locations, and any specific considerations associated with sample acquisition, were recorded on preformatted data sheets. Following sample collection, all samples were logged into a master logbook (bound notebook) and given a unique alphanumeric identification number. Any specific sample preservation, storage, or on-site analysis information also was noted. Sample labels and chain-of-custody seals were completed and affixed to the sample container. Finally, chain-of-custody forms were completed by personnel involved in the sampling handling.

All samples with a holding time and cooling requirements (4°C) were packed daily on ice in a cooler chest that was taped shut, sealed with a chain-of-custody seal, and shipped by overnight express to the analytical laboratory. Each sample was logged into a master file book for recordkeeping. Once received by the laboratory the samples were immediately integrated into the laboratory sample identification and tracking system, given internal numbers, and placed in refrigerators maintained exclusively for sample storage for this project. Samples that did not require minimal holding times and cooling (i.e. solids for metals analysis and samples for ultimate analysis) were distributed out of the central laboratory. Extensive chain-of-custody and tracking mechanisms were employed for all sample transfer activities.

5.2 ANALYTICAL PROCEDURES

Samples of feed, scrubber water, scrubber solids, scrubber makeup water, furnace ash, liquid and solids from flue gas sampling, and samples from ambient air sampling were analyzed for parameters as specified in Tables 9 and 10. Descriptions of the analytical methods are presented in the following sections.

5.2.1 Solid Streams Analysis

Solid streams including feed, furnace ash, and scrubber solids were analyzed for PCBs, PCDD/PCDF, metals, volatile and semivolatile priority pollutants plus the ten highest peaks, (V-PP+10, SV-PP+10), TCLP, and EP Toxicity (metals) characteristic, chlorine, moisture, ash, higher heating value, ultimate analysis, and density.

5.2.2 Liquid Streams Analysis

The scrubber liquid samples including scrubber water and scrubber makeup water were analyzed for PCBs, PCDD/PCDF, pH, chlorine, metals, V-PP +10, SV-PP+10, total organic carbon (TOC), total suspended solids, and total dissolved solids. The scrubber water also was analyzed for TCLP and EP Toxicity (metals) characteristic.

5.2.3 Stack Gas and Primary Furnace Offgas Analysis

Gases were analyzed using continuous emission monitoring systems (CEMs) for carbon monoxide, carbon dioxide, oxygen, nitrogen oxides, and total hydrocarbons. Grab samples also were collected during each test run and analyzed for carbon dioxide and oxygen using an Orsat analyzer (EPA Method 3).

Three EPA Method 5 samples were collected for analysis of particulate matter, moisture, flowrate, and HCl.

Three integrated sets of VOST samples were collected for analysis of V-PP+10. Six VOST tube pairs and two condensate vials were collected for each VOST sample, for a total of 18 tube pairs and 6 condensate vials. Three analyses were obtained from each set of 6 VOST tube pairs collected; one condensate vial also was analyzed.

Three EPA Modified Method 5 (MM5) samples were collected for analysis of soluble chromium.

Three SASS samples were collected and analyzed for PCBs. In addition, three other SASS samples were collected and analyzed for PCDD/PCDF and SV-PP+10.

5.2.4 Ambient Air

Ambient air samples were collected daily upwind and downwind of the incineration system. The Hi-Vol filters collected ambient air particulate matter that was analyzed for metals, and PUF samples were analyzed for PCBs.

5.2.5 V-PP+10 Analysis

V-PP+10 analyses were conducted on several types of samples, including solid, liquid, and gas phase samples. The solid and liquid incinerator samples included:

- Feed
- Furnace Ash
- Scrubber Water
- Scrubber Makeup Water
- Scrubber Solids

The gas phase samples included stack gas and primary furnace offgas samples collected by VOST. V-PP+10 analysis of each type of sample used the following techniques.

5.2.5.1 Stack Gas and Primary Furnace Offgas Analysis for V-PP+10

The VOST was used to collect samples of the stack gas and primary furnace offgas for quantitation of the V-PP+10. The tenax and tenax/charcoal sorbent traps were analyzed according to SW-5040. Volatile compounds were separated and detected using GC/MS as outlined in SW-8240.

5.2.5.2 Liquid and Solid Sample Analysis for V-PP+10

V-PP+10 compounds in liquid and solid samples were analyzed using SW-8240. The methods detailed the purge and trap procedure for preparing field samples for GC/MS analysis.

5.2.6 SV-PP+10 Analysis

SV-PP+10 analyses were conducted on all samples streams including:

- Feed
- Furnace Ash
- Scrubber Water
- Scrubber Makeup Water
- Scrubber Solids
- Primary Furnace Offgas
- Stack Gases

5.2.6.1 Stack Gas and Primary Furnace Offgas Analysis for SV-PP+10 Analysis

SV-PP+10 analysis using SW-8270 was performed on the stack gas and primary furnace offgas samples collected using the SASS. SV-PP+10 and PCDD/PCDF were analyzed in the same SASS sample by splitting the solvent extract for the two analyses. Surrogates applicable to both analyses were injected into the samples prior to extraction. SV-PP+10 analysis was completed prior to initiation of cleanup steps for the PCDD/PCDF analysis.

5.2.6.2 Liquid and Solid Sample Analysis for SV-PP+10

Samples of the feed,scrubber water, scrubber makeup water, scrubber solids, and furnace ash were analyzed by SW-8270. Liquid samples were extracted using SW-3520. Solid samples were extracted using SW-3540. Extracts of liquid and solid samples were analyzed for semivolatile organic contaminants using GC/MS.

5.2.7 PCB Analysis

EPA 680 was used to analyze stack gas, primary furnace offgas, PUF samples (ambient air), and solid and liquid samples for

PCBs by GC/MS. GC/MS analysis using selected ion monitoring is superior for PCB analysis of gas samples. This type of analysis monitors for ions indicative of biphenyls with two chlorines, three chlorines, etc. The results are presented as the sum of individual chlorinated biphenyl congener instead of mixtures of such congeners, as defined by Aroclor number, which is most common in GC/ECD analysis.

5.2.7.1 Stack Gas and Primary Furnace Offgas Analysis for PCBs

Samples of the stack gas and primary furnace offgas were collected using a SASS train with XAD-2 as the adsorbent resin for PCB analysis. The samples were recovered using methanol and methylene chloride. The SASS train provides three subsamples: (1) the glass fiber filter; (2) methanol and methylene chloride rinses of the probe, filter holder, and the condenser/resin trap; and (3) the aqueous condensate. Each subsample was extracted separately and then combined for analysis.

5.2.7.2 Liquid and Solid, and Ambient Air Sample Analysis for PCBs

EPA 680 was followed for PCB analysis of the feed, furnace ash, scrubber water, scrubber water makeup, scrubber solids, and ambient air particulates. Solid samples were Soxhlet-extracted using SW-3540. Liquid samples were extracted using SW-3520.

5.2.8 PCDDs and PCDF Analysis

All sampled streams were analyzed for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) using SW-8280.

5.2.8.1 Stack Gas and Primary Furnace Offgas Analysis for PCDDs and PCDFs

Stack gas and primary furnace offgas samples for analysis of PCDDs and PCDFs were collected using a SASS train and were analyzed according to SW-8280. PCDD/PCDF analyses were performed on the same SASS samples as SV-PP+10 by splitting the SASS sample extract for each analysis.

5.2.8.2 Liquid and Solid Samples Analysis for PCDDs and PCDFs

The liquid and solid samples collected for PCDD and PCDF measurements were analyzed using SW-8280. Aqueous samples were extracted by continuous liquid/liquid extraction according to SW-3520. SW-3540, which is a Soxhlet extraction technique, was used to extract solids.

5.2.9 Metals

Samples of the stack gas, primary furnace offgas and ambient air particulate matter, solids, and liquids were analyzed for metals by inductively coupled argon plasma emission spectroscopy (ICAP) using SW-6010, and by atomic absorption spectroscopy (AAS) using SW-7060, 7421, 7841, 7740, and 7470/7471. The solid samples and particulate matter collected on the filter of the EPA Method 5 train and high volume ambient air samplers were solubilized using SW-3050. Prior to analysis, liquid samples were prepared by using SW-3020. Lithium metaborate and sodium carbonate fusion techniques were used to recover silicon and boron.

The samples were analyzed for a total of thirty-one elements. The volatile elements (lead, arsenic, antimony, selenium, and mercury) were analyzed by AAS. Arsenic, antimony, lead, and selenium were determined using graphite furnace techniques (SW-7060, 7041, 7421, and 7740, respectively). Mercury was determined by the cold vapor technique (SW-7470/7471).

Aqueous samples (SW-7470) were acidified prior to analysis.

5.2.9.1 Continuous Monitoring - Vaporous Lead

Radian Corporation, through work with the Electric Power Research Institute and the Department of Energy, has developed an experimental continuous vapor phase monitor for selected metals, including lead. The monitor was not defined by an approved EPA method or QAPP review but was incorporated in the overall program to study the monitoring system's ability to provide real time data, which can allow a process evaluation for the control of metals emissions. Continuous monitoring of vaporous lead in the primary furnace offgas was conducted to determine the incinerator operating conditions required to destroy the organic material while minimizing the volatilization of lead from the contaminated soil. The initial results did not detect vapor phase lead concentrations in the PCC offgas samples at levels less than 2.7 ppb; the results were inconclusive and the program was aborted. The Test Plan for this activity, as proposed and defined by Radian Corp., is included in Appendix E, Volume II. The results of these monitoring studies are included in Appendix F, Volume II.

5.2.10 Soluble Chromium

Stack gas and primary furnace offgas samples were analyzed for soluble chromium (hexavalent chromium) using EPA M218.4. By this method, the hexavalent chromium is chelated using ammonium pyrrolidine dithiocarbamate. The chelated chromium then is extracted from the sample medium using methyl isobutyl ketone. The solvent extract then is analyzed by flame atomic absorption spectroscopy.

The stability of hexavalent chromium is not completely understood, and the method recommends that chelation and extraction be carried out as soon as possible. The stack gas samples for soluble chromium analysis were chelated and extracted on site after sample collection. The results did not detect soluble chromium concentrations at levels less than 264 ppb and were inconclusive.

5.2.11 EP Toxicity Leaching Procedure

The feed, furnace ash, scrubber water, and scrubber solids were analyzed by the RCRA Characteristic of EP Toxicity (SW-1310). The method involves the acidic extraction of solid samples followed by analysis of specific trace metals. The EP Toxicity analysis was performed for trace metals only: specifically, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.

5.2.12 Toxicity Characteristic Leaching Procedure

The feed, furnace ash, scrubber water, and scrubber solids were analyzed by the proposed Toxic Characteristic Leaching Procedure (TCLP). TCLP was proposed by EPA to expand the toxicity characteristic to include additional chemicals and to incorporate a new extraction procedure. Extraction for volatiles involves acidic extraction in a zero-headspace extractor, which is rotated in an end-over-end fashion at 30±2 rpm. Extraction for metals and semivolatiles uses the same procedure except that it is done in a glass container rather than the zero-headspace. The metals were analyzed as described for EP Toxicity. The organic contaminants were analyzed using SW-8240 and 8270.

5.2.13 Other Analyses

The feed, furnace ash, and scrubber solids were analyzed for chlorine, ash, and ultimate analysis, and the feed for higher heating value.

5.2.13.1 Chlorine Analysis

Chlorine analyses of the feed, furnace ash, and scrubber solids were performed using ASTM D808. The samples were combusted in an oxygen bomb containing an alkaline solution. The alkaline solution was analyzed for chlorine (as chloride) using titration.

5.2.13.2 Ash Analysis

The ash content of the feed, furnace ash, and scrubber solids were determined using ASTM D3174. The sample was ignited and, after burning, was ashed at 1427^{0}F in a muffle furnace. The residue then was weighed.

5.2.13.3 Ultimate Analysis (C, H, O, S, N, Moisture)

The feed, furnace ash, and scrubber solids were analyzed for elemental concentrations using A003 for ultimate analysis. The procedure involves the analysis of carbon, hydrogen, nitrogen, sulfur, and moisture. Oxygen is determined by difference. A003 is a conglomerate of ASTM methods. ASTM D3178 analyzes for carbon and hydrogen by burning the samples in a combustion system followed by fixation of the products of combustion in an absorption train for analysis. Nitrogen is analyzed by ASTM D3179. The nitrogen in the sample is converted to ammonium salts by destructive digestion. Ammonia is recovered and analyzed titrimetrically. ASTM D3177 is used to measure sulfur using bomb calorimetry. The recovered sulfur is precipitated as $BaSO_4$ and determined gravimetrically. Moisture is determined by ASTM D3173, which is a gravimetric technique involving drying of the sample.

5.2.13.4 Higher Heating Value Analysis

The higher heating value (HHV) of the solid waste feed was determined using a bomb calorimeter, according to ASTM D2015-77 for solid waste.

5.2.14 TSS and TDS Analysis

The concentration of Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) present in the scrubber liquid effluent and scrubber water inlet was determined using gravimetric procedures EPA M160.1 and M160.2, respectively.

5.2.15 pH Analysis

The pH of the scrubber liquid samples was determined using a portable pH meter and combination electrode with temperature compensation in accordance with EPA M150.1.

5.2.16 Density

The bulk density of the feed, furnace ash, and scrubber solids were determined using a gravimetric/volumetric method.

5.2.17 Particulate Matter

Particulate material was measured in the stack gas and primary furnace offgas using EPA Method 5.

5.2.18 Flue Gas Moisture

The moisture content of the gas streams was determined using the technique specified in EPA Method 4.

5.2.19 HCl Determination

For the determination of HCl in the stack gas and primary furnace offgas, samples of gas were passed through a series of impingers immersed in an ice bath. The first two impingers contained 200 mL of 0.1 N NaOH and were Greenburg-Smith type impingers. Following the first two impingers are a dry, modified Greenburg-Smith impinger and an impinger containing a desiccant. The sample was analyzed using an ion chromatograph following Method 27 from the "FGD Chemistry and Analytical Methods Handbook," Volume 2, Radian Corporation, July 1984.

5.2.20 Carbon Dioxide

During the sampling for HCl in the stack gas and primary furnace offgas, the collection of CO_2 in the 0.1 N NaOH impinger is a consideration that had to be addressed. Because the impinger solutions are caustic, CO_2 also was removed from the stack gas. Thus, the metered sample gas volume was low by the amount of CO_2 removed by the impinger solutions. To account for the CO_2 removal, the 0.1 N NaOH impinger solutions were analyzed for carbonate; total gas volume then was corrected.

5.2.21 Oxygen and Carbon Dioxide Analysis

Grab bag samples of the stack gas and primary furnace offgas were collected in the field according to EPA Method 3 for CO_2 and O_2. These samples were analyzed within 3 hours of collection using an Orsat analyzer.

5.2.22 Total Organic Carbon

Total carbon was measured using a carbonaceous analyzer by quantitatively converting the organic and inorganic carbon in a sample to carbon dioxide, which then was measured by an infrared detector. Total inorganic carbon is determined by sparging carbonates from the sample as CO_2, which is measured by IR. The UV-catalyzed oxidation of organics is not used. Total organic carbon is calculated from the difference of total carbon/total inorganic carbon.

5.3 SAMPLING AND ANALYTICAL REPORT

The Sampling and Analytical Report is included as Appendix B, Volume II.

SECTION 6

PERFORMANCE DATA EVALUATION

6.1 INTRODUCTION

Based on the operating data presented in Section 4 and Appendix A, and the analytical results presented in Appendix B, and Appendices D-G, an evaluation was conducted to determine the effectiveness of the Shirco Pilot-scale Infrared Incineration System in treating the feed at the Demode Road Superfund Site under a series of varied operating conditions.

A total of 17 runs were conducted. Three runs were performed under design operating conditions to assess overall unit operation and system performance (Phase I). These runs were conducted at 1600°F PCC temperature, a 2200°F SCC temperature, and a PCC residence time of 20 min. Each of the three runs was sufficiently long (6 to 10 hours) to gather a large enough sample of stack gas to analyze it for PCBs. An additional run was conducted at the same operating conditions to obtain specific stack samples that had not been successfully collected during two of the previous runs.

Fourteen runs were conducted under varying operational parameters to evaluate their effect on system performance and energy consumption. These runs were conducted for approximately one hour under varied operating conditions that included the PCC temperature (900, 1200, 1400, and 1600°F), SCC temperature (1800 and 2200°F), PCC feed residence time (10, 15, 20, and 25 minutes), and PCC combustion air flow (on or off to simulate oxidizing or non-oxidizing/pyrolytic PCC atmosphere). Specific discussions addressing the field operations of each run and the operating conditions under which it was carried out are provided in Section 4.

This section addresses the Shirco unit's ability under the various operating conditions to meet specific evaluation objectives that have been set in the following areas:

- o DRE levels for PCBs and the presence of PICs in the stack gas. The regulatory standards are 99.99% DRE under the Resource Conservation and Recovery Act (RCRA) and 99.9999% DRE under the Toxic Substances and Control Act (TSCA).

- Level of hydrogen chloride (HCl) and particulates in the stack gas. The RCRA standard for HCl in the stack gas is 1.8 kg/hr (4 lb/hr) or 99 wt% HCl removal efficiency. The RCRA standard for particulate emissions in the stack gas is 180 mg/dscm (0.08 gr/dscf).

- Level of residual PCBs in the furnace ash at normal and varied operating conditions.

- Mobility of heavy metals, particularly lead, in the furnace ash as compared to the feed.

- Mobility of heavy metals in the furnace ash as compared to the RCRA Extraction Procedure Toxicity (EP Tox) Characteristic (as measured by the EP Tox test) and the proposed toxicity characteristic (as measured by the Toxicity Characteristic Leaching Procedure (TCLP)).

- Level of residual heavy metals and organic compounds, and other physical and chemical characteristics in the scrubber water discharged from the unit.

- The operating conditions that reduce energy consumption without decreasing soil decontamination effectiveness.

- Effect of varying operating conditions on residual levels of heavy metals and organics in the furnace ash versus the levels in the feed.

- Adherence of the quality assurance (QA) procedures to the requirements of the RREL-approved QA Project Plan (Category II), as defined by the Document No. PA QAPP-0007-GFS, "Preparation Aid for HWERL's Category II Quality Assurance Project Plans," June 1987.

6.2 CHARACTERISTICS OF THE FEED

The results of the analyses of the composites of the grab samples of feed taken during each of the test runs are reported in Appendix B and summarized in Table 11. Highlights of these results are as follows:

- During the runs conducted on soil feed mixed with 3 wt% fuel oil, the analyses of the feed samples showed the expected trend of increased HHV, moisture content and carbon, hydrogen, and oxygen contents, and decreased ash content, as compared to the excavated soil feed with no fuel oil addition.

- Total PCBs concentration ranged from 10.2 to 669 ppm and averaged 272 ppm.

TABLE 11. FEED CHARACTERISTICS (b,c)

Characterization	Average w/o Fuel Oil	Average w/Fuel Oil
Density, g/cc	2.31	2.23
High Heating Value (HHV), Btu/lb	210	588
Moisture, wt%	10.81	12.68
Carbon, wt% (a)	2.45	3.54
Hydrogen, wt% (a)	1.48	1.64
Oxygen, wt% (a)	11.87	12.86
Nitrogen, wt% (a)	0.10	0.11
Sulfur, wt% (a)	0.02	0.03
Chlorine, wt% (a)	0.11	0.09
Ash, wt% (a)	83.98	81.75

Organics	Range (d)	Average (e)
Total PCBs, ppm	10.2-669	272
Total PCDD, ppb	ND	ND
Total PCDF (TCDF), ppb	ND-0.1	0.065
Semivolatiles, ppm		
Bis(2-ethylhexyl)phthalate	<1.0-5.5	5.5
Volatiles, ppm		
Methyl ethyl ketone	31-34	32
Trichloroethene	<2.0-17	10.2

Metals, ppm	Range(d)	Avg(e)	Metals, ppm	Range(d)	Avg(e)
Antimony	<0.3-26	2.7	Mercury	<0.005-0.3	0.11
Arsenic	9.8-13	10.6	Nickel	19-110	30.8
Barium	390-940	591	Selenium	<0.3	<0.3
Beryllium	<0.097	<0.097	Silver	<0.87-6.2	2.3
Cadmium	2.6-11	4.4	Thallium	<8.7	<8.7
Chromium	59-180	84.9	Vanadium	16-26	20.4
Copper	15-34	18.1	Zinc	200-590	301
Lead	290-3000	778			

(a) Elemental analyses (wt%) are on a moisture-free basis. Average wt% values do not total to 100%.

(b) ND indicates not detected, or less than detection limits which vary for each PCDD/PCDF homolog.

(c) < indicates ND at detection limit (as indicated).

(d) Range values shown represent all data.

(e) Average values shown represent the average of all data. Values below detection limits were included in the average at the detection limit.

- Several samples of the feed contained small quantities of TCDFs ranging from 0.04 to 0.1 ppb.

- Volatile and semivolatile organic compounds including methyl ethyl ketone, trichloroethene, and bis(2-ethylhexyl)phthalate were measured in feed samples at concentrations less than 50 ppm. Methyl ethyl ketone and trichloroethene were also detected in solvent blanks and are attributed to analytical laboratory contamination.

- In addition to lead, the primary heavy metal contaminant, whose concentrations ranged from 290 to 3,000 ppm and averaged 778 ppm, several other metals were present at average concentrations exceeding 50 ppm including barium (591 ppm), zinc (301 ppm), and chromium (85 ppm). Other heavy metals were present in lesser concentrations, as reported in the table.

6.3 CHARACTERISTICS OF THE FURNACE ASH

The results of the analyses of the composites of the grab samples of furnace ash taken during each of the test runs are reported in Appendix B and summarized in Tables 12 and 13. Highlights of these results are as follows:

- The total concentration of PCBs ranged from 0.004 to 3.396 ppm. Additional discussion on the residual PCBs in the furnace ash is presented in Section 6.4.

- Two samples of furnace ash contained 0.07 and 0.3 ppb of TCDF during Runs 17 and 18 conducted at a 900°F PCC operating temperature; the normal PCC operating temperature is 1,600°F. These runs were also conducted without the input of PCC combustion air to simulate non-oxidizing or pyrolytic combustion conditions. The low PCC temperature and pyrolytic environment could have led to the incomplete desorption or incineration of TCDF present in the feed or to the production of TCDF from the incomplete combustion of PCBs in the feed.

- The ultimate analysis data tend to substantiate the incomplete desorption of contaminants from the feed, as discussed above for TCDF desorption, and in Section 6.4 for PCBs. At the low PCC operating temperature of 900°F and pyrolytic combustion conditions, the presence of higher TCDF and PCB concentrations in the furnace ash is complemented by higher carbon contents and lower noncombustible ash contents in the furnace ash that are indicative of an incomplete desorption or incineration process. For the three runs conducted at a PCC operating temperature of 900°F, carbon contents averaged 2.08 wt%, vs. 0.80 wt% for the other runs; noncombustible ash contents averaged 93.88 wt% vs. 98.04 wt% for the remaining runs.

TABLE 12. CHARACTERISTICS OF THE FURNACE ASH - ORGANICS AND METALS ANALYSES

	Operating Conditions PCC		Organics (h)						Metals (i)			
Run No.	Temp. (°F)	Residence Time (min.)	PCB (ppm)	PCDF (TCDF) (ppb)	(g) MeC (ppm)	(g) MEK (ppm)	(g) TeCE (ppm)	(g) TrCE (ppm)	Pb (ppm)	Ba (ppm)	Zn (ppm)	Cr (ppm)
18	900(a,b)	20	2.079	0.07					1,000	720	380	86
17	900(b)	20	3.396	0.30					1,400	940	410	94
16	900(b)	25	0.168	ND					860	940	410	85
10	1200	20	0.115(d)	ND					1,100	970	380	77
14	1200	15	0.077	ND					1,000	1,000	420	100
9	1200(b)	25	0.108(d)	ND					1,200	1,000	360	78
11	1200(b)	20	0.066(d)	ND					1,200	760	510	76
13	1200(b)	15	0.025(d)	ND					2,000	690	350	74
15	1200(a,b)	15	0.066(d)	ND					1,000	1,800	640	84
5	1400	20	0.087(d)	ND					1,600	950	420	81
1	1600	20	0.037	ND	ND	36	ND	5	1,100	1,400	360	78
2	1600	20	0.112	ND	980	64	6.4	3.9	1,300	1,200	410	79
3	1600	20	0.003	ND	ND	40	ND	ND	1,100	1,000	340	110
1-2	1600(f)	20	(f)	ND					420	1,100	350	71
7	1600	10	0.045(d)	ND					1,700	940	400	75
6	1600(a)	15	0.117(d)	ND					840	790	380	62
19	1600(a)	15(c)	0.004	ND					1,500	1,800	440	79
8	1600(a,b)	15	0.061(d)	ND					800	1,100	420	68

(a) Waste feed blended with 3 wt% fuel oil.

(b) Non-oxidizing atmosphere.

(c) PCC bed depth at 1 inch. All other tests at 1-1/2 inches.

(d) PCB levels below analytical detection limits. Total shown is sum of detectable limits indicated in analyses.

(e) ND - nondetectable value.

(f) Run was conducted to make up for incomplete semivolatile organics, PCDD/PCDF, soluble chromium and stack gas particulate samplings during Runs 1 and 2.

(g) MeC: Methylene chloride; MER: Methyl ethyl ketone; TeCE: Tetrachloroethylene; TrCE: Trichloroethene.

(h) Reported data is presented. For runs with no values shown, organic analyses were not conducted.

(i) Only heavy metals with concentrations greater than 50 ppm are shown.

TABLE 13. CHARACTERISTICS OF THE FURNACE ASH - ULTIMATE ANALYSES

	Operating Conditions PCC		Characterization Ultimate Analyses (e)								
Run No.	Temp. (°F)	Residence Time (min)	Moisture (wt%)	C (wt%)	H (wt%)	O (wt%)	N (wt%)	S (wt%)	Cl (wt%)	Ash (wt%)	Density (g/cc)
18	900(a,b)	20	0.83	3.04	0.20	6.56	0.07	<0.01	0.05	90.08	2.85
17	900(b)	20	0.50	1.95	0.17	2.67	0.07	0.04	0.06	95.04	2.85
16	900(b)	25	0.61	1.24	0.08	2.05	0.07	<0.01	0.05	96.51	2.86
10	1200	20	0.83	1.17	0.09	1.26	0.04	<0.01	0.04	97.40	2.89
14	1200	15	0.58	1.21	0.09	3.48	<0.02	<0.01	0.06	95.16	2.85
9	1200(b)	25	0.61	0.48	0.08	0.51	<0.02	0.04	0.03	98.86	2.74
11	1200(b)	20	0.59	1.19	0.10	1.31	0.04	0.05	0.05	97.26	2.97
13	1200(b)	15	0.77	1.47	0.12	2.35	0.06	<0.01	0.05	95.95	2.87
15	1200(a,b)	15	1.36	1.30	0.15	1.92	0.03	0.04	0.04	96.52	2.87
5	1400	20	0.67	0.57	0.07	0.64	<0.02	<0.01	0.05	98.67	2.74
1	1600	20	0.48	0.36	0.07	<0.5	<0.02	<0.01	0.05	99.78	2.71
2	1600	20	0.57	0.50	0.13	<0.5	<0.02	<0.01	0.05	99.74	2.71
3	1600	20	1.54	0.50	0.17	<0.5	<0.02	<0.01	0.05	99.34	2.70
1-2	1600(d)	20	0.61	0.49	0.12	<0.5	0.04	<0.01	0.04	99.13	2.79
7	1600	10	0.69	0.92	0.07	0.93	<0.02	<0.01	0.05	98.03	2.75
6	1600(a)	15	0.95	0.57	0.10	1.06	<0.02	<0.01	0.04	98.23	2.76
19	1600(a)	15(c)									
8	1600(a,b)	15	0.71	0.45	0.10	0.66	<0.02	0.05	0.05	98.69	2.73

(a) Wastefeed blended with 3 wt% fuel oil.

(b) Non-oxidizing atmosphere.

(c) PCC bed depth at 1 inch. All other tests at 1-1/2 inches.

(d) Run 1-2 was conducted to make up for incomplete samplings during Runs 1 and 2.

(e) Elemental analyses on dry basis.

- For the Phase I Runs 1-3, volatile and semivolatile organic analyses were conducted on the furnace ash samples. No semivolatile organics were detected. Volatile compounds including methylene chloride, methyl ethyl ketone, tetrachloroethene, and trichloroethene were measured in the furnace ash samples in concentrations ranging from 3.9 to 64 ppm with one sample containing 980 ppm of methylene chloride. Methyl ethyl ketone and trichloroethene were also detected in solvent blanks and methylene chloride is commonly employed in laboratory procedures; therefore, these compounds may be products of incomplete combustion and/or the result of laboratory contamination.

- In addition to lead, for which concentrations ranged from 420 to 2,000 ppm and averaged 1,173 ppm, several other metals were present at average concentrations exceeding 50 ppm including barium (1061 ppm), zinc (410 ppm), and chromium (81 ppm).

6.4 RESIDUAL PCBs IN FURNACE ASH

During the demonstration test, a total of 17 runs were conducted at varying operating conditions. In addition to the DRE levels, which are an indication of the performance of the Shirco Pilot-Scale Infrared Incineration System and its ability to meet RCRA and/or TSCA regulatory standards, the reduction of PCB concentration from the feed to the furnace ash is also a measure of the unit's ability to effectively destroy PCBs and produce a furnace ash with a PCB concentration below the TSCA guidance level of 2 ppm.

As shown by the data presented in Table 12, two samples of furnace ash exceeded the TSCA guidance levels and contained 3.396 and 2.079 ppm of total residual PCBs. The samples were produced during Runs 17 and 18 conducted at a 900°F PCC operating temperature (20 minutes residence time), which is significantly lower than the normal PCC operating temperature of 1600°F. These runs were also conducted without the input of PCC combustion air to simulate non-oxidizing or pyrolytic combustion conditions. At this low PCC temperature and pyrolytic condition, these higher total residual PCB levels in the furnace ash may be the result of the incomplete combustion of PCBs in the feed. This is further substantiated by the residual TCDF present in the furnace ash samples from these same two runs, as discussed in Section 6.3. The remaining runs conducted at 1200°F, 1400°F, and 1600°F resulted in total residual PCB concentrations in the furnace ash ranging from 0.003 to 0.117 ppm. Run 16, which was also conducted at a 900°F PCC operating temperature, but with an increased PCC residence time of 25 minutes, resulted in a total furnace ash PCB concentration of 0.168 ppm with no detectable TCDF. It is possible that the increased residence time in the PCC may have offset the low 900°F PCC operating temperature and provided the additional processing time for the satisfactory destruction of the PCBs in the feed.

6.5 MOBILITY OF HEAVY METALS

EP Tox and TCLP tests were conducted on the feed, furnace ash, scrubber water, and scrubber solids. The tests were conducted to document any trend or evidence which, as a result of the thermal treatment, shows reduced mobility of heavy metals in effluent streams based on the toxicity characteristic standards, as compared to the feed. The results of these tests are reported in Appendix B and Appendix G. Table 14 summarizes the data reported for the heavy metal of particular concern in these tests, lead, as analyzed in the leachate from the feed and the furnace ash. Highlights of the results are as follows:

6.5.1 Mobility of Heavy Metals - Feed and Furnace Ash

In order to determine whether heavy metals, particularly lead, would leach from the furnace ash produced in the Shirco Pilot-Scale Infrared Incineration System, EP Tox and TCLP tests were conducted to determine the mobility of heavy metals from the furnace ash as compared to the feed.

- The initial EP Tox analyses for lead in the leachate ranged from 0.05 to 0.67 ppm for the feed and 0.05 to 4.1 ppm for the furnace ash. The initial TCLP analyses ranged from 0.35 to 1.80 ppm (with one sample at 7.0 ppm) for the feed and 0.05 to 4.1 ppm (with one sample at 6.2 ppm) for the furnace ash.

- A comparison of the EP Tox and TCLP analyses conducted on the furnace ash and the feed does not show any trend or evidence that indicates reduced mobility of lead from the furnace ash versus the feed as a result of the thermal treatment. The comparison did reveal that the concentrations of lead in the TCLP leachates from both the feed and the furnace ash were consistently higher than the corresponding EP Tox test results on the same samples.

- When several samples were retested to verify the results, the concentrations of lead in the EP Tox leachates (4.9 ppm feed, 3.0 pm furnace ash) were higher than during the initial tests, and in direct reversal from the original data, exceeded corresponding TCLP leachate concentrations (2.8 ppm feed, 1.4 ppm furnace ash). The results of the retest again did not indicate reduced mobility of lead from the furnace ash versus the feed as a result of the thermal treatment.

TABLE 14. COMPARISON OF LEACHABLE LEAD IN THE FEED AND FURNACE ASH

	Operating Conditions PCC		EP Toxicity		TCLP	
Run No.	Temp. (^{O}F)	Residence Time (min.)	Feed (mg/L) (ppm)(f)	Ash (mg/L) (ppm)(f)	Feed (mg/L) (ppm)(f)	Ash (mg/L) (ppm)(f)
18	900(a,b)	20	0.29	0.38	0.81	2.90
17	900(b)	20	0.67	0.89	0.88	6.20
16	900(b)	25	0.32	0.88	7.00	3.80
10	1200	20	0.05	4.10	0.56	1.60
14	1200	15	0.20	0.38	0.44	3.60
9	1200(b)	25	0.12	0.14	0.53	0.05
11	1200(b)	20	0.20	0.06 4.90(e)	0.71	4.10 2.80(e)
13	1200(b)	15	0.18	(g)	0.53	(g)
15	1200(a,b)	15	0.21	0.46	0.96	0.82
5	1400	20	0.07	ND	0.89	0.15
1	1600	20	0.15	0.05	0.67	ND
2	1600	20	0.20	ND	0.35	ND
3	1600	20	0.23	0.13	1.30	0.05
1-2	1600(d)	20	0.14	0.28	0.49	1.80
7	1600	10	0.25	ND	1.73	1.00
6	1600(a)	15	ND	0.43	0.66	0.17
19	1600(a)	15(c)	0.53	0.27	1.80	0.23
8	1600(a,b)	15	0.07 3.00(e)	1.10	0.55 1.40(e)	2.40

ND = Not Detected.

(a) Waste feed blended with 3 wt% fuel oil.
(b) Non-oxidizing atmosphere.
(c) PCC bed depth at 1 inch. All other tests at 1-1/2 inches.
(d) Run was conducted to make up for incomplete semivolatile organics, PCDD/PCDF, soluble chromium, and stack gas particulate samplings on other runs.
(e) Data from additional EP Tox and TCLP tests as presented in Appendix G.
(f) EP Tox and proposed TCLP toxicity characteristic standard is 5 mg/L.
(g) No data due to broken sample container.

6.5.2 Mobility of Heavy Metals - EP Tox and Proposed TCLP Toxicity Characteristic Standards

The results of the EP Tox and TCLP tests conducted on the feed, furnace ash, and scrubber water were below the EP Tox and proposed TCLP toxicity characteristic standards of 5 mg/L arsenic, 100 mg/L barium, 1 mg/L cadmium, 5 mg/L chromium, 5 mg/L lead, 0.2 mg/L mercury, 1 mg/L selenium, and 5 mg/L silver, except for one feed sample at 7.0 mg/L lead (TCLP) and one furnace ash sample at 6.2 mg/L lead (TCLP), as discussed above. A comparison of the EP Tox and TCLP analyses on all the sampled streams does not show any trend or evidence that indicates reduced mobility of heavy metals as a result of the thermal treatment.

6.6 DESTRUCTION AND REMOVAL EFFICIENCY (DRE) OF PCBs

The Phase I Runs 1-3 were designed to operate for a sufficiently long period of time to enable the SASS to sample sufficient stack gas volume for analyses of PCBs. PCBs also were analyzed in the feed, furnace ash, scrubber solids, scrubber water, and scrubber makeup water to provide a mass balance of PCBs during these runs.

The PCB analyses performed on the feed indicated detectable but lower-than-expected PCB levels based on the pretest sampling and analysis discussed in Section 4.1. The PCB content of the ten-sector pretest composite sample was 626 ppm or 626,000 ng/g compared to the analyses of the feed employed during Runs 1-3, which varied from 10,200 ng/g to 35,200 ng/g as shown on Table 15. These low-feed PCB concentrations contributed to stack gas PCB concentrations that were less than the analytical detection limit for Runs 1 and 2 and minimally detectable for Run 3. However, the PCBs were destroyed and not found in the furnace ash or the stack gas.

As discussed in Section 4.2.2, the excavation of the feed soil from the designated sectors containing highest PCB and/or lead contamination was performed in as efficient a manner as possible using large-scale front-end loading equipment in an irregular and highly sloped terrain. The mixing of the excavated soil was performed by the front-end loader continuously shoveling the waste feed soil pile. Although the waste preparation contractor indicated that this method would produce a homogeneous waste feed source, the results discussed above did not confirm our expectations.

In order to provide the most conservative DRE values, the detectable levels of PCBs in the feed along with the sum of the detection limits for each PCB congener in the stack gas (as reported in Appendix B) were employed. DRE levels for PCBs during the Phase I runs were calculated based on the above quantities and ranged from greater than 99.9922% to greater than 99.9976%, as shown in Table 15.

With a RCRA DRE standard of 99.99%, the runs indicated DRE levels in excess of the RCRA standard. In order to have proved the unit's ability to meet or exceed the TSCA DRE standard of 99.9999%, the feed required higher PCB concentrations.

For Run 3, where a detectable PCB concentration in the stack gas also was obtained, a DRE of 99.9982% was calculated. This value, however, may be suspect because of apparent concentrations of similar PCB congeners in a reagent blank. Thus the detectable PCB concentration in the stack gas may have been the result of contamination during analysis.

The Phase I runs indicated DRE levels in excess of the RCRA standard of 99.99%. Based on the operating and sampling and analytical data, the feed required a PCB concentration exceeding 1000 ppm in order to calculate a DRE of 99.9999%. With an average PCB concentration of 626 ppm in the ten-sector composite sample and actual PCB concentrations ranging from 10.2 to 35.2 ppm during Runs 1-3, as discussed above, the waste feed required spiking with additional PCB material to the 1000 ppm concentration level in order to have ensured a unit operation that would have met the TSCA DRE standard of 99.9999%.

In all of the above discussions concerning the DRE calculations and results, the analytical method employed for the determination of PCB concentrations in the feed and stack gas samples was Method 680, as defined and approved in the program's QAPP (Appendix C). At this time, however, it appears that the two main standard analytical methods for measuring PCBs, Method 680 and Method 8080, may not be adequate for a treatment process involving thermal destruction of PCBs, such as the tested Shirco technology. Method 680 presents difficulties with detection limits for individual PCB congeners, and Method 8080 is not applicable to samples that have had their Arochlor patterns altered due to thermal treatment. Without a specific PCB analytical procedure to follow, Method 680 was employed and conservative DRE values were obtained utilizing the resulting analytical data and a defined calculation method, as discussed above.

TABLE 15. DESTRUCTION AND REMOVAL EFFICIENCY OF PCBs

	Run No.			
	1	2	3(a)	3(b)
Date (Time)	11/3/87 (1228-1800)	11/4/87 (1608-1924)	11/5/87 (0938-1330)	11/5/87 (0938-1330)
PCB concentration in waste feed	10200	35200	20400	20400
Waste feedrate (g/hr)	30178	33163	35113	35113
PCB Mass feedrate (ng/hr x 10^8)	3.078	11.673	7.163	7.163
PCB concentration in stack gas (ng/m^3)	<110.7	<142.9	<177.5	68.0
Stack gas flowrate (dscmm)	3.60	3.26	3.14	3.14
PCB mass emission rate (ng/hr x 10^4)	<2.391	<2.795	<3.344	1.281
DRE (%)	>99.9922	>99.9976	>99.9953	99.9982

(a) Calculated DRE for Run 3 based on the sum of the detection limits for each PCB congener in the stack gas. This calculated DRE is consistent with the DRE calculation method for Runs 1 and 2.

(b) Calculated DRE for Run 3 based on a detectable PCB concentration in the stack gas.

6.7 OTHER ORGANIC STACK GAS AND PCC OFFGAS EMISSIONS

The results of the analyses of the stack gas and PCC offgas samples obtained from the SASS and VOST sampling trains during the Phase I runs are presented in Appendix B and summarized in Table 16. Highlights of these results are as follows:

- Several volatile and semivolatile organic compounds were detected in the stack gas at concentrations less than 100 ppb and below established standards for direct inhalation.
- Low levels of several phthalate compounds were also detected in blank samples and may be traced to contamination from plastic components in the process, sampling equipment, or laboratory apparatus.
- Several volatile organic compounds including benzene and toluene were detected in the stack gas and the scrubber makeup water and may be attributable to contamination from the makeup water, although PIC formation is a possibility.
- Other volatile and semivolatile organic compounds, which probably represent PICs, were detected. They include halomethanes; chlorinated species including chlorobenzene and methylene chloride; volatile organics including xylenes, styrene and ethylbenzene; oxygenated hydrocarbons including acetone and acrolein; carbon disulfide; and p-chloro-m-cresol.
- Dioxins and furans were not detected in the stack gas samples.
- The majority of the organic compounds present in the PCC offgas samples at levels less than 500 ppb were also present in the stack gas. The additional destruction and removal of organics that takes place in the SCC and emissions scrubbing systems reduced the concentration of these organic compounds in the corresponding stack gas samples.

6.8 ACID GAS REMOVAL

The concentration of HCl in the stack gas was measured during the EPA Method 5 sampling conducted during the Phase I Runs 1-3. During Run 2, the sampling train malfunctioned and no results were obtained. Run 1-2 was conducted to obtain the additional set of data. The chlorine concentration in the feed was obtained from the ultimate analyses of the feed samples taken during each of the runs. The complete results of these EPA Method 5 and ultimate analyses are reported in Appendix B and summarized in Table 17. Highlights of these results are as follows:

TABLE 16. PCC OFFGAS AND STACK GAS ORGANIC EMISSIONS

	Average Concentration*	
	PCC Offgas	Stack Gas
Semivolatile organics, ppb		
Benzoic acid	2.5	6.5
Bis(2-ethylhexyl)phthalate	2.0	2.4
p-Chloro-m-cresol	1.4	--
Diethylphthalate	24.0	9.1
Di-n-butylphthalate	4.4	9.3
Volatile organics, ppb		
Acetone	7.9	4.7
Acrolein	86.7	4.0
Benzene	200.0	16.0
Bromomethane	4.7	0.7
2-Butanone	2.6	--
Carbon disulfide	2.6	9.3
Carbon tetrachloride	0.4	0.2
Chlorobenzene	10.4	1.4
Chloroform	0.7	0.1
Chloromethane	74.7	8.3
1,4-Dichloro-2-butene	6.6	--
Ethylbenzene	5.7	0.4
Iodomethane	16.6	2.3
Methylene chloride	6.6	14.4
Styrene	12.5	3.7
Tetrachloroethene	0.2	0.3
Toluene	34.2	1.3
1,1,1-Trichloroethane	0.3	0.2
Trichlorofluoromethane	1.2	0.2
Vinyl chloride	4.6	--
Xylenes	3.3	0.7

* Average values shown represent the average of all data. Values below detection limits were included in the average at the detection limit.

TABLE 17. ACID GAS REMOVAL EFFICIENCY

	Run No.		
	1	3	1-2*
Date	11/3/87	11/5/87	11/6/87
Time	16:30-17:50	13:01-13:54	10:57-12:55
Stack gas flowrate (dscfm)	139	119	132
HCl conc. (ppmv)	0.4	2.0	3.0
HCl emission rate (g/hr)	0.181	0.590	0.998
Waste feedrate (g/hr)	30178	35113	31856
Ultimate analysis waste feed (wt% Cl)	0.09	0.09	0.11
HCl to scrubber (g/hr)	27.93	32.49	36.03
HCl removal efficiency (wt%)	99.35	98.18	97.23

* Run 1-2 was conducted to make up for the incomplete EPA Method 5 sampling run for Run 2.

- Based on measured stack gas flowrates and HCl concentrations, HCl emission rates were calculated and ranged from 0.181 to 0.998 g/hr. These values are below the RCRA performance standard of 1.8 kg/hr (1800 g/hr) of HCl or a 99 wt% removal efficiency.

- Based on the ultimate analyses of the feed, chlorine concentrations ranged from 0.09 to 0.11 wt%, equivalent to an HCl flowrate to the scrubber ranging from 27.93 to 36.03 g/hr.

- From the above, calculated HCl or acid gas removal efficiencies ranged from 97.23 to 99.35 wt%.

- With the HCl emissions rate being below the RCRA performance standard and the scrubber water being maintained at a neutral pH of 7.25-8.65 with no caustic addition, the unit satisfactorily met acid gas removal requirements and displayed sufficient capacity to process higher acid gas loadings.

The impinger train of the EPA Method 5 runs was not analyzed for sulfate to determine the concentration of SO_2 in the stack gas; therefore, SO_2 removal efficiency could not be calculated. For the Phase I tests, sulfur concentrations in the waste feed were less than 0.01 wt% as presented in Appendix B. At these low levels, total SO_2 flows and loadings on the scrubber system were minimal.

6.9 PARTICULATE EMISSIONS

Mass particulate loadings in the stack were measured during the EPA Method 5 sampling conducted during the test program. The results are reported in Appendix B and summarized in Table 18.

The data indicate that for the entire demonstration, particulate emissions ranged from 7 to 69 mg/dscm, which is lower than the RCRA standard of 180 mg/dscm and indicative of satisfactory particulate emissions control at a conservative venturi pressure drop of less than 20 inches WC.

6.10 ANALYSIS OF SCRUBBER MAKEUP WATER, SCRUBBER WATER, AND SCRUBBER SOLIDS

The results of the analyses of the samples of scrubber makeup water, scrubber water, and scrubber solids taken during the test runs are reported in Appendix B and summarized in Tables 19 and 20. Highlights of these results are as follows:

- Scrubber makeup water was transported to the site in a tank truck that may have contained some residual contamination prior to fill up. Samples of scrubber makeup water were taken at the end of each run. No PCBs, dioxins, furans, or semivolatile organic compounds were detected. Several

TABLE 18. PARTICULATE EMISSIONS

Run No.	Date	Time	Stack Gas Flowrate (dscfm)	Oxygen Content (wt%)	Particulate Emissions Concentration		
					Measured (gr/dscf)	7% O_2 (gr/dscf)	7% O_2 (mg/dscm)
1	11/03/87	1630-1750	139	8.5	0.0093	0.010	23
2	11/05/87	1301-1354	119	9.8	0.024	0.030	69
1-2*	11/06/87	1057-1255	132	7.2	0.015	0.015	34
10	11/09/87	1936-1036	131	10.7	0.0061	0.0083	19
14	11/09/87	1126-1226	122	12.3	0.0042	0.0068	16
5	11/09/87	1346-1446	120	7.5	0.0048	0.0050	11
6	11/10/87	0931-1031	127	8.6	0.0045	0.0051	12
8	11/10/87	1121-1221	119	8.3	0.0029	0.0032	7
15	11/10/87	1313-1413	99	9.8	0.0035	0.0044	10
18	11/10/87	1508-1608	136	11.1	0.0028	0.0040	9
7	11/11/87	0904-1004	140	8.9	0.0073	0.0084	19
9	11/11/87	1132-1422	129	9.8	0.0082	0.0100	23
11	11/11/87	1322-1422	100	9.2	0.0078	0.0093	21
13	11/11/87	1511-1611	109	9.0	0.0078	0.0091	21
16	11/12/87	1028-1128	125	9.0	0.0071	0.0083	19
17	11/12/87	1235-1335	109	11.4	0.0055	0.0080	18
19	11/13/87	1010-1110	112	9.3	0.0055	0.0066	15

* Run 1-2 was conducted to make up for incomplete samplings on Runs 1 and 2, that include the particulate sampling for Run 2.

volatile organics including benzene, toluene, and trichloroethene were measured at concentrations less than 15 ppm. The concentrations of heavy metals were all less than 0.2 ppm. Scrubber makeup water was also analyzed for pH, total suspended solids (TSS), total dissolved solids (TDS), chloride, and total organic carbon (TOC). Average values were 7.94 pH, 0.12 mg/L TSS, 339 mg/L TDS, 25.7 mg/L chlorides, and 2.3 mg/L TOC.

- Samples of the water recirculation through the venturi scrubber system, referred to as scrubber water, were also taken at the end of each run. PCB concentrations were less than 200 ppt and no dioxins, furans, or semivolatile organic compounds were detected. Small quantities of benzene (2 ppm) and toluene (5.7 to 11 ppm) were measured in several of the samples and are attributable to the similar contaminants in the scrubber makeup water. The concentrations of heavy metals in the scrubber water were all less than 1 ppm except for barium, which ranged from 0.2 to 2.2 ppm, and lead, which ranged from 0.12 to 1.8 ppm. Scrubber water was also analyzed for pH, TSS, TDS, chloride, and TOC. Average values were 7.71 pH, 116.1 mg/L TSS, 1272 mg/L TDS, 630.9 mg/L chlorides, and 2.7 mg/L TOC. A comparison of the high TSS, TDS, and chloride values as compared to the scrubber makeup water illustrate the effect of the venturi scrubber system on removing particulate carryover from the vapor stream prior to its exit at the stack.

- Insufficient quantities of scrubber solids in the scrubber water were available for representative analyses.

6.11 OVERALL DISPOSITION OF METALS

Total metals analyses were conducted on samples from each of the test runs of the feed, furnace ash, scrubber makeup water, and scrubber water. Metals analyses on the scrubber solids were incomplete and suspended due to the small quantity of recoverable solids.

Total metals analyses were also conducted on the particulate material and probe and nozzle washes collected on the EPA Method 5 sampling trains from the PCC offgas and stack gas streams during Phase I Runs 1, 3, and 1-2. Run 1-2 was conducted to make up for incomplete samplings during Runs 1 and 2 and, in particular, the malfunctioned EPA Method 5 sampling during Run 2.

The results of these analyses are reported in Appendix B and summarized in preceding tables. An overall mass balance of lead through the unit and a breakdown of the calculated lead concentration in the feed, furnace ash, and PCC offgas and stack gas particulates, is summarized in Tables 21 and 22. Highlights of these results are as follows:

TABLE 19. SCRUBBER MAKEUP WATER ANALYSIS

Characterization	Range (c)	Average (d)
pH	7.48 - 8.33	7.94
TSS, mg/L	0 - 0.84	0.12
TDS, mg/L	306 - 366	339
Cl, mg/L	24.8 - 26.9	25.7
TOC, mg/L	< 1 - 6	2.3
Organics		
Total PCBs, ppt	ND (a)	ND (a)
Total PCDD/PCDF, ppt	ND (a)	ND (a)
Semivolatiles, ppb	ND (a)	ND (a)
Volatiles, ppm		
Benzene	2.0 - 13.0	6.3
Toluene	< 2.0 - 5.3	3.2
Trichloroethene	< 2.0 - 7.1	3.7
Metals		
All metals concentrations less than 0.2 ppm.		

(a) ND indicates not detected or less than detection limits which vary for each PCB congener, PCDD/PCDF homolog, and organic compound.

(b) < indicates ND at detection limit (as indicated).

(c) Range values shown represent all data.

(d) Average values shown represent the average of all data. Values below detection limits were included in the average at the detection limit.

TABLE 20. SCRUBBER WATER ANALYSIS

	Range (c)	Average (d)
Characterization		
pH	6.19 - 8.65	7.71
TSS, mg/L	49.4 - 557	116.1
TDS, mg/L	722 - 2653	1272
Cl, mg/L	513.7 - 675.3	630.9
TOC, mg/L	< 1 - 6	2.7
Organics		
Total PCBs, ppt	ND (a)	ND (a)
Total PCDD/PCDF, ppt	ND (a)	ND (a)
Semivolatiles, ppb	ND (a)	ND (a)
Volatiles, ppm		
Benzene	< 2.0 - 2.0	2.0
Toluene	< 2.0 - 11.0	6.2
Metals, ppm		
Barium	0.2 - 2.2	0.8
Lead	0.12 - 1.8	0.7

All other metals concentrations less than 1 ppm and average concentrations less than 0.3 ppm.

(a) ND indicates not detected or less than detection limits which vary for each PCB congener, PCDD/PCDF homolog, and organic compound.

(b) < indicates ND at detection limit (as indicated).

(c) Range values shown represent all data.

(d) Average values shown represent the average of all data. Values below detection limits were included in the average at the detection limit.

- The data indicate that a high concentration of the majority of the heavy metals that enter the unit with the feed remain with the furnace ash.

- An overall mass balance of lead through the unit was calculated based on the analysis of lead in the samples, the measured feedrate as weighed during the runs' operating periods, the calculated furnace ash flow based on the ultimate analysis of ash in the feed sample, and the measured particle mass and gas volume obtained from the Method 5 sampling trains. The balance shows that the majority of the lead entering the unit with the feed also remained with the furnace ash.

- Phase I results indicate an average lead mass flowrate of 28.3 g/hr in the feed, 37.0 g/hr in the furnace ash, 0.206 g/hr in the PCC offgas particulates, and 0.109 g/hr in the stack gas particulates. The quantity of lead leaving the unit with scrubber water effluent is approximately 0.204 g/hr based on the maximum measured concentration of 1.8 ppm lead in the scrubber water and an overall approximate water flowrate of 30 gph.

- In contrast to the high mass flowrates of lead in the feed and furnace ash as compared to the particulates, the PCC offgas particulates sampled during the Phase I runs contained an average of 5364 ppm of lead and the stack gas particulates contained an average of 15,830 ppm of lead. By contrast, the average concentration of lead in the feed was 1550 ppm. Although the concentration of lead in the particulate matter increases as the process flow progresses through the unit, the actual mass flow of lead decreases as the gas stream is cooled and treated through the emissions control system.

- For the Phase I runs sampling and analysis procedures were conducted to evaluate vaporous lead concentrations in the PCC offgas and soluble chromium concentrations in the PCC offgas and stack gas particulates. The special sampling for vapor phase lead and soluble chromium were unable to detect any of either metal at levels less than 2.7 ppb and 264 ppb, respectively; therefore, the evaluations were inconclusive.

- Other heavy metals, particularly barium and zinc, with average concentrations exceeding 100 ppm in the feed (barium 591 ppm, zinc 301 ppm) were also present in high concentrations relative to other heavy metals, in the furnace ash (barium 1061 ppm, zinc 410 ppm) and scrubber water (barium 0.8 ppm, zinc 0.3 ppm).

TABLE 21. LEAD FLOWS THROUGH THE SYSTEM

Test	Feed g/hr	Ash g/hr	PCC particulates g/hr	Stack particulates g/hr
1	90.6	28.7	0.039	0.122
3	19.3	32.1	0.278	0.098
1-2*	35.1	11.2	0.302	0.108
2	46.5	36.0		
10	22.9	33.4		
14	37.7	36.5		
5	22.1	39.4		
6	36.2	34.8		
8	27.2	35.8		
15	16.8	37.2		
18	21.4	29.8		
7	32.1	73.4		
9	16.9	29.5		
11	20.4	33.5		
13	18.8	67.3		
16	8.6	21.2		
17	21.0	37.4		
19	15.6	49.0		
Average	28.3	37.0	0.206	0.109

* Run 1-2 was conducted to make up for incomplete samplings on Runs 1 and 2 that include the PCC offgas and stack gas particulate sampling for Run 2.

TABLE 22. LEAD CONCENTRATIONS IN FEED, ASH, AND PARTICULATES

Test	Feed ppm	Ash ppm	PCC particulates ppm	Stack particulates ppm
1	3000	1100	3939	24493
3	550	1100	6114	8990
1-2*	1100	420	6040	14017
Average	1550	873	5364	15830

* Run 1-2 was conducted to make up for incomplete samplings on Runs 1 and 2 that include the PCC offgas and stack gas particulate sampling for Run 2.

6.12 OPTIMUM OPERATING CONDITIONS

Phase II was designed to examine over varying operating conditions the energy consumption and changes in the residual levels of heavy metals and organics in the furnace ash versus the levels in the feed.

Based on the energy consumption data presented in Tables 7 and 8 (Section 4.2.3.2), Table 23 presents a comparative summary of the power and energy consumption of the unit at varied operating conditions that did not affect the performance of the unit. Highlights of this data are as follows:

- A reduction in the PCC operating temperature from 1600^{o}F to 1200^{o}F reduced the average PCC power usage 48% from 0.2294 to 0.1200 kwhr/lb feed.
- A reduction in the SCC operating temperature from 2200^{o}F to 1800^{o}F reduced the average propane fuel consumption by 51% from 3997 to 1952 Btu/lb feed.
- The use of 3 wt% fuel oil to supplement the heating value of the feed further decreased PCC power usage by 26% to 67% at PCC operating temperatures of 1600^{o}F and 1200^{o}F, respectively, with accompanying increases in overall feedrate of 32% and 26%.

- Based on the data presented in Table 11 (Section 6.2), the addition of the fuel oil increased the average HHV of the feed from 210 to 588 Btu/lb. This increase in heating value is equivalent to a savings of 0.11 kwhr/lb feed. Based on the data presented in Table 23, reductions or savings in power when fuel oil was added to the feed were 0.07 and 0.09 kwhr/lb feed, which closely approximates the calculated value of 0.11 kwhr/lb feed based on heating value.
- The costs for fuel oil and its attendant facilities still must be examined for specific applications to determine the cost effectiveness of a fuel oil additive to the feed. The cost of power, the moisture content of the feed, the total heating value of the feed, PCC residence time, and the overall PCC design heating input will all impact on the necessity for and the quantity of the addition of fuel oil to the feed.

As discussed in previous sections, the results did not provide any trend or change in the residual levels of the heavy metals and organics in the furnace ash versus the levels in the feed as the operating conditions were varied and PCC operating temperatures were maintained at 1200° to 1600°F. At an abnormally low PCC operating temperature of 900°F, without the input of combustion air to simulate non-oxidizing or pyrolytic combustion conditions, total PCB and TCDF concentrations in the furnace ash increased. The increases may indicate that these PCC conditions led to incomplete desorption or incineration of PCB and TCDF and to the production of TCDF from the incomplete combustion of PCBs in the feed.

6.13 QA SUMMARY

The Phase I and II runs had a well-defined quality assurance/quality control program to ensure the collection of accurate data. This program was developed as part of the test program preparation activities and was formalized in the RREL-approved QA Project Plan (Category II). All of the sampling and analytical work was conducted in accordance with this QA Project Plan, and the results include data quality credibility statements and information that confirm the satisfactory precision and accuracy of the data reported.

Overall, the QA/QC data indicate that the measurement data are acceptable and defensible. Samples were analyzed for PCBs, dioxins and furans, volatiles, semivolatiles, metals, TCLP extracts (volatiles, semivolatiles, and metals), EP extract metals, chloride in filters, hexavalent chromium, total organic carbon, and solids characterization. The most significant problems noted, from a QA/QC standpoint, were that the analyses for PCBs and semivolatiles were not carried out within the holding time specified by the QAPP and selenium was not recovered in the matrix spike samples for solids, TCLP and EP extracts, and filters.

TABLE 23. OPTIMUM OPERATING CONDITIONS - ENERGY CONSUMPTION

Run No.	Feed-rate (lb/hr)	1600° PCC temp. power (kwhr/lb feed)	2200°F SCC temp. Propane fuel (Btu/lb feed)	Run No.	Feed-rate (lb/hr)	1200°F PCC temp. power (kwhr/lb feed)
1	66.53	0.2975	4458	10	78.68	0.1913
2	73.11	0.2495	3914	14	95.41	0.1608
3	77.41	0.2497	4560	9	62.95	0.1360
1-2	70.23	0.2919	3847	11	73.85	0.0678
7	114.10	0.1827	3210	13	88.29	0.1189
Avg	80.28	0.2543	3997	Avg	79.84	0.1350
	w/fuel oil		1800° SCC		w/fuel oil	
6	110.77	0.1914	1819	15	100.33	0.0451
8	120.00	0.1367	1608			
19	88.29	0.2356	2428			
Avg	106.35	0.1879	1952	Avg	100.33	0.0451
	Overall Avg	0.2294			Overall Avg	0.1200

Analyses of solid, liquid, and filter samples for PCBs met most of the specifications in the QAPP, except for holding time. Blank recoveries were acceptable for all matrices. Surrogate spike recoveries tended to be low for feed, higher weight PCBs in liquids, and ambient air filters. Recoveries were generally low for matrix spike/matrix spike duplicate compounds for furnace ash, scrubber makeup water, and the filter blank sample. Repeatability of the matrix spike/matrix spike duplicate samples was excellent except for one sample of scrubber makeup water. Recovery for the other sample of scrubber makeup water was within specifications.

Low recoveries for the PCB surrogate and matrix spike compounds suggest that reported results for field samples are probably lower than the true concentrations.

Analyses of dioxins and furans in solid and liquid samples met most of the acceptance criteria specified in the QAPP. Blank sample analyses showed no contamination from analytical sources. Although surrogate recoveries were low for the higher molecular weight dioxins and furans for both types of matrices, none of the native dioxins and furans were detected in field samples. Surrogates were recovered at about 30%, which suggests that actual field sample concentrations are probably no greater than about three times the laboratory-stated detection limit. Repeatability for the compounds reported in two pairs of duplicates was excellent.

Quality control data for volatiles in solids, liquids, VOST samples, and TCLP extracts showed no significant problems in these analyses. Some common laboratory contaminants (methyl ethyl ketone, 1,2-dibromo-3-chloropropane, and xylenes) were detected in more than one blank analyzed with the solid samples. None of these compounds should be considered a significant contaminant since they were detected at less than five times the method detection limit. Recoveries of surrogate spike and matrix spike compounds was excellent for all four matrix types.

No quality control problems were detected with the semivolatile analyses except for the holding time violation. Surrogate and matrix spike recoveries are acceptable for almost all compounds. Surrogate recovery was low for 2-fluorophenyl in TCLP extracts of feed and furnace ash samples. This may have been due to exceeded holding time; however, recovery of the other five surrogate compounds was acceptable.

Analyses of metals were performed on solids, liquids, TCLP and EP extracts, and filter samples. Several elements (arsenic, barium, beryllium, cadmium, chromium, copper, lead, silver, vanadium, and zinc) were detected in the blanks above the detection limit. However, only one element (barium), in one blank sample, was recovered at greater than five times the detection limit. Therefore, analytical contamination should not be considered to be a major factor in the reported recoveries for field samples. Matrix spike recovery was acceptable for all elements except silver in filter samples, and selenium in all matrices but liquids. Precision of analyses measured by matrix spike duplicate analyses and analytical duplicate analyses was good. As expected, precision of analyses of solid samples was not as good as those for other matrices.

Silver was not recovered in matrix spikes of filter samples. A footnote on the laboratory report states that silver in the spike material is incompatible with the digestion process. Any silver originally present in the field samples might also be precipitated out in the digestion and, therefore, not detected.

Recovery for selenium was poor in all matrices except liquids. Recovery for three of four samples (0%, 0%, and 1%) averaged 0.33 percent. Selenium was not recovered in matrix spikes of TCLP or EP extracts, or filter samples. This implies that selenium could have been present and not detected in the field samples (i.e., false negative results).

Review of the results for chloride analyses in filters, hexavalent chromium, total organic carbon, and solids characterization shows good quality control. No problems were detected in the data.

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